



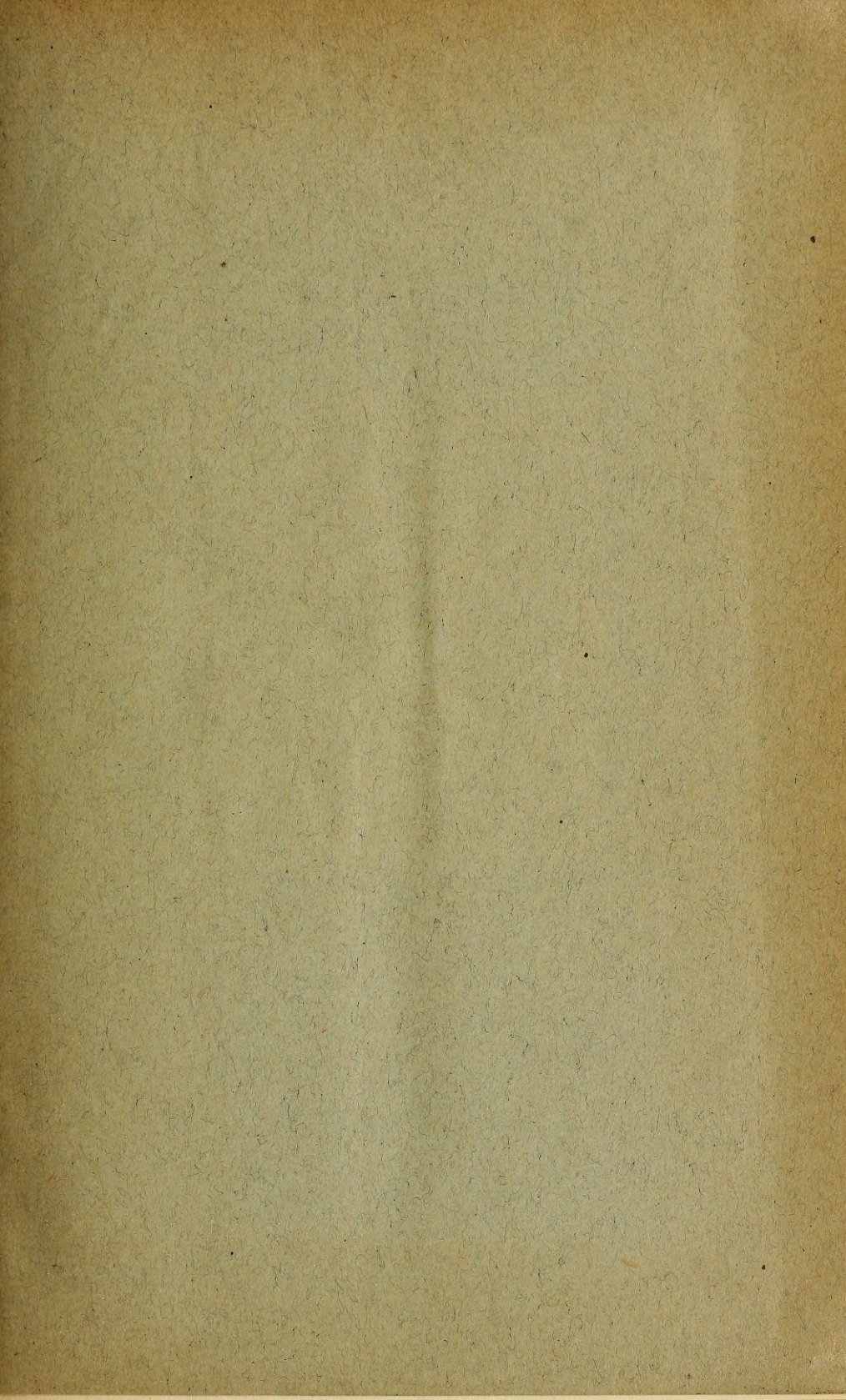
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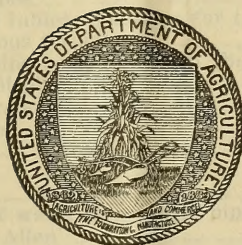
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JOHN L. COBBS, Jr.,

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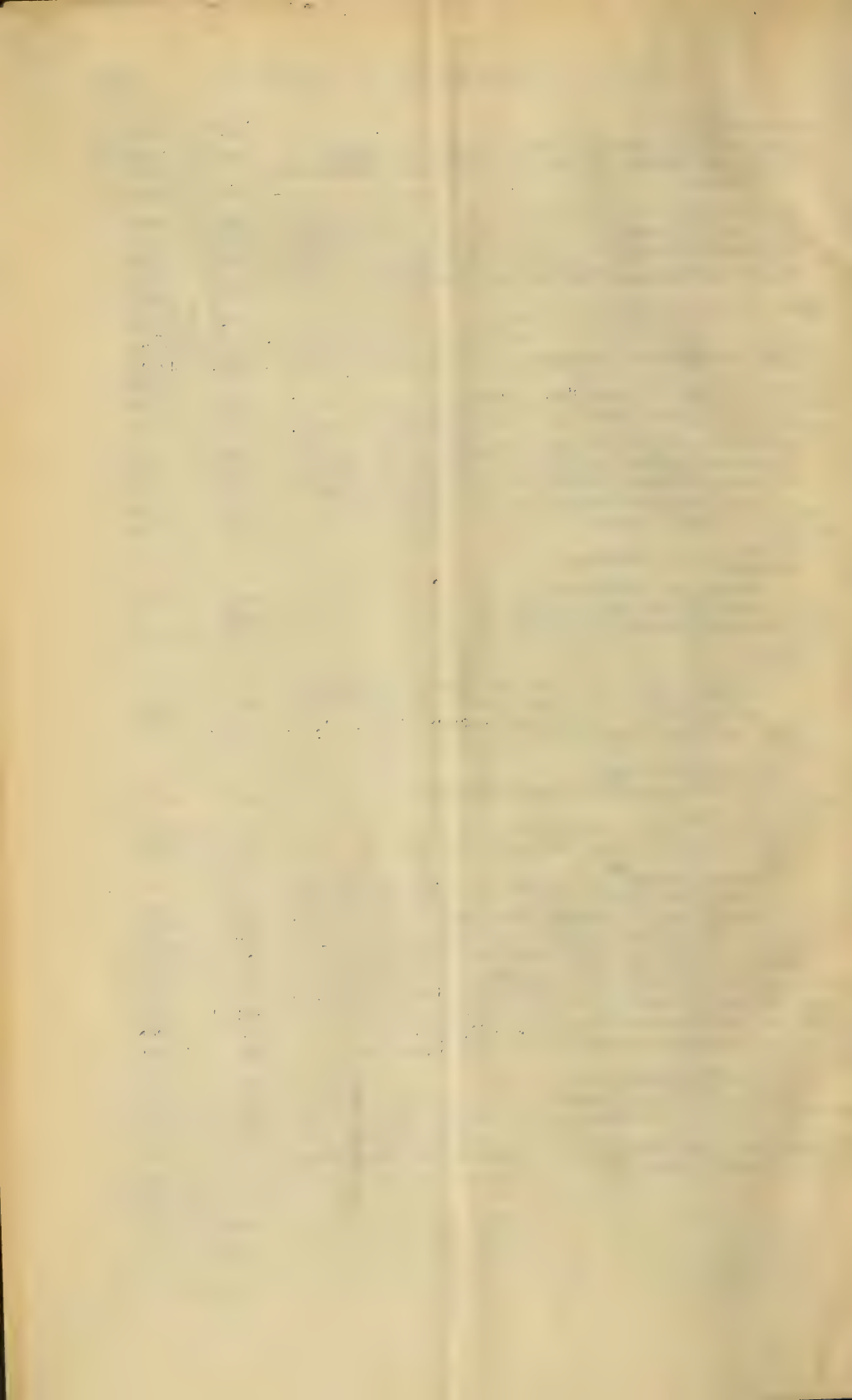
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OFFICE OF THE SECRETARY.

Contribution from the Office of Farm Management.

H. C. TAYLOR, Chief.



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COST OF PRODUCING APPLES IN FIVE COUNTIES IN WESTERN NEW YORK 1910-1915.

By G. H. MILLER, *Assistant Agriculturist.*

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INTRODUCTION.

The western New York fruit belt is the oldest commercial apple-growing district in the United States. Few other regions in America have had the benefit of the experience of former generations in the production of apples. Thus, among 218 apple growers upon whose experience this bulletin is based, there are men who have orchards 30 to 60 years of age, as well as those who have recently planted young orchards.

In this region the apple orchard is only a part of the farm business, other fruits and such crops as beans, potatoes, and hay being extensively grown. This bulletin treats of the relation the orchard bears to these other enterprises, of the orchard practices followed by the more successful growers, the effect of these practices on yields, the returns derived from different systems of orchard management, and the cost of maintaining orchards under each system.¹ Detailed

NOTE.—Acknowledgment is due to the Office of Horticultural and Pomological Investigations of the Bureau of Plant Industry for material assistance in the preparation of this bulletin; also to Messrs. S. M. Thomson and J. C. Folger, who aided in securing the necessary data.

information is presented as to the time required to perform each operation, the necessary equipment, the size of the orchard, the age of the trees, the yield of fruit, and other related factors.



FIG. 1.—Map of New York State, showing the fruit districts. Shaded portion indicates area in which this study was made.

The factors considered in arriving at the annual cost of apple production have been classified as follows:

Labor for maintenance.	Labor in handling.	Materials used.	Fixed charges.
Manuring.....	Hauling.....	Barrels.....	Taxes.
Fertilizing.....	Picking.....	Spray materials.....	Insurance.
Pruning.....	Sorting.....	Manure.....	Equipment charge.
Disposing of brush.....	Packing.....	Fertilizers.....	Machine hire.
Plowing.....	Hauling to station.....	Gasoline, oil, etc.....	Interest.
Other cultivating.....	Cull labor.....	Cover-crop seed.....	Building charge.
Thinning.....			
Propping.....			
Spraying.....			
Miscellaneous.....			
Cover-crop labor.....			

This study was made in the most intensive apple-producing area in western New York, including the counties of Monroe, Niagara, Ontario, Orleans, and Wayne. (See figs. 1, 2, 3, and 4.) These five counties produced 45 per cent of all the apples grown in New York in 1909 (Thirteenth Census).

¹ In the summer of 1914 the Office of Farm Management began a study relative to the cost of production of apples in the five more important apple-producing counties of western New York. The same farmers were visited in the summer of 1916 in order to obtain additional information and note any changes made in the methods of orchard management. Over 200 representative farmers were visited. A method of study similar to that already used in other regions was adopted. Data were secured from each farmer as to the time required for the different operations, as to equipment, cost of labor, spraying materials, barrels, etc., and as to land and orchard values.

SUMMARY OF RESULTS.

Following is a brief summary of the more important averages brought out in this study of 218 bearing apple orchards in western New York.

Acreage:

Per farm, 118.65.

Bearing apple orchard, 14.00.

In other fruit, 20.44.

In crops, 73.76.

Per cent of farm in bearing apple orchard, 13.38.

Yield per acre, 84.1 barrels (exclusive of culls).



FIG. 2.—View of typical farming country in western New York.

Trees per acre, 35.

Age, 40 years.

Investment:

Per farm, \$25,424.

Bearing apple orchard, \$7,321.

Per acre, bearing apple orchard, \$514.

Per cent apple orchard is of total investment, \$29.85.

Total net cost of production per barrel, \$1.4124.

Maintenance, \$0.2859.

Handling, \$0.1434.

Material, \$0.5835.

Fixed, \$0.3996.

Per cent of total net cost of production:

Maintenance, 20.24.

Handling, 10.15.

Material, 41.31.

Fixed, 28.30.

LABOR.

The farms considered in this investigation are of such size that it is usually necessary for an owner or operator to hire one or two men from 8 to 12 months, and ordinarily some extra help during the harvest periods. Data obtained in 1916 show that in 1915 men with families, hired by the year, were usually paid from \$300 to \$600, depending on the man and the responsibility placed upon him. They are often furnished a house, sufficient garden space for the growing of truck for family use, milk, and fuel, which privileges, as evaluated by the owners, amount to from \$75 to \$200 annually.

Unmarried men, hired by the month, received from \$25 to \$45, with meals and lodging, which is valued at 75 cents to \$1 per day. When board was not included \$30 to \$60 was paid. The average period of employment is about 8 months, from April 1 to November 15.



FIG. 3.—View of one of the intensive fruit-growing areas of western New York.

Men hired by the day received \$1.50 to \$2.50 per 10-hour day. During the last three years it has been increasingly difficult to obtain experienced help, especially at harvest time.

Since all the work, except in some instances the picking and the sorting, is done by the operator and his regular farm hands, the rate of 20 cents per hour has been used for all labor, unless otherwise stated.

All horse labor is figured at 15 cents per hour, which, from previous investigations, is a fair charge.

Figure 5 shows the seasonal distribution of labor and the average time for each operation in the bearing apple orchards of western New York.

FARM INVESTMENT.

The average investment on the 218 farms studied was \$25,423.72. The apple-orchard investment, averaging \$514 per acre, was 35 per

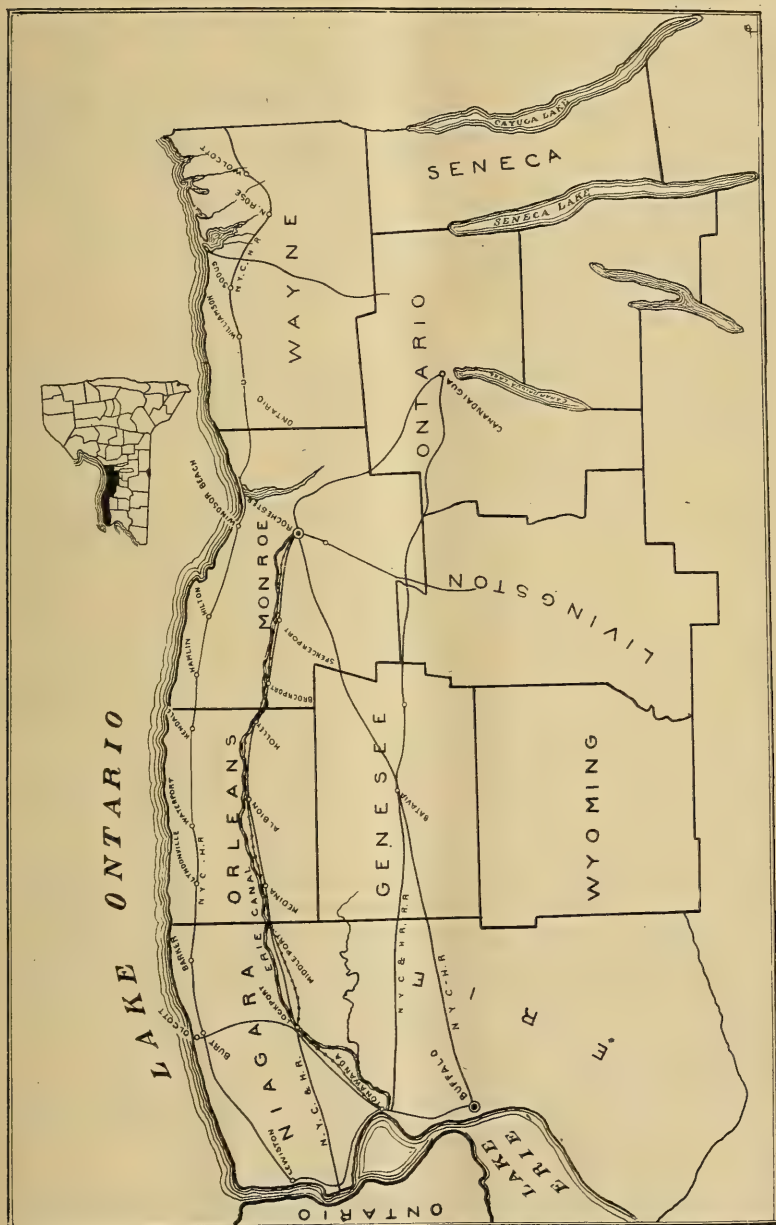


FIG. 4.—Some of the principal shipping points in western New York.

cent of the total land and improvement investment. Table I gives the itemized average investment per farm in the different counties.

TABLE I.—Average size of farm and of bearing orchard, and average investment per farm and per acre (218 farms, western New York, 1910–1915, inclusive).

	Wayne.	Ontario.	Monroe.	Orleans.	Niagara.
Number of records.....	44	42	47	50	35
Average acreage:					
Total.....	103.34	139.21	116.03	121.10	113.24
In bearing apple orchard.....	13.88	11.31	13.31	17.04	13.97
Average investment:					
Total.....	\$24,181.08	\$21,437.30	\$26,838.91	\$28,517.43	\$25,449.60
Land and improvement.....	\$21,089.77	\$17,645.83	\$23,616.13	\$25,202.75	\$22,379.64
In bearing apple orchard.....	\$7,044.55	\$4,331.65	\$7,359.83	\$10,517.84	\$6,638.57
Equipment.....	\$1,129.32	\$1,326.33	\$1,079.13	\$1,144.58	\$1,121.43
Horses.....	\$945.00	\$1,147.00	\$1,150.00	\$1,186.00	\$1,134.00
Other stock.....	\$518.00	\$804.00	\$541.00	\$480.00	\$376.00
Average investment per acre:					
Total.....	\$237.48	\$163.88	\$241.84	\$251.30	\$232.67
Apple orchard.....	\$499.58	\$373.12	\$561.11	\$629.58	\$475.09
Per cent value of apple orchard is of total investment per farm.....	32.93	21.63	29.34	36.26	27.36
Per cent value of apple orchard is of land and improvement investment per farm.....	38.65	26.62	33.69	41.25	31.63
Per cent of farm in apple orchard.....	14.53	10.36	12.97	15.11	13.66
Horses per farm.....	4.9	6.0	5.5	5.6	5.9

OPERATIONS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAN HRS.	HORSE HRS.
MANURE	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	7.6	15.2
PRUNE	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	31.8	
BRUSH				-----	-----	-----	-----	-----	-----	-----	-----	-----	8.1	7.6
FERTILIZE				-----	-----	-----	-----	-----	-----	-----	-----	-----	1.4	2.8
PLOW				-----	-----	-----	-----	-----	-----	-----	-----	-----	6.0	12.0
CULTIVATE				-----	-----	-----	-----	-----	-----	-----	-----	-----	8.5	18.5
THIN				-----	-----	-----	-----	-----	-----	-----	-----	-----	23.1	
PROP				-----	-----	-----	-----	-----	-----	-----	-----	-----	4.3	3.6
COVER CROP				-----	-----	-----	-----	-----	-----	-----	-----	-----	1.7	2.2
SPRAY *				-----	-----	-----	-----	-----	-----	-----	-----	-----	24.0	24.0
PICK								-----	-----	-----	-----	-----	50.0	
PACK								-----	-----	-----	-----	-----	36.7	
MARKET								-----	-----	-----	-----	-----	11.0	22.0
CULL LABOR								-----	-----	-----	-----	-----	6.2	4.9
AVERAGE ANNUAL TIME													170	90

FIG. 5.—Seasonal distribution of operations with average time per acre in bearing apple orchards, western New York. The average time is given for each operation, though the sum of these figures does not necessarily show the labor expended annually, as a grower may not practice each operation every year. There was an average annual expenditure of 170 man hours and 90 horse hours per acre on the farms studied.

The total equipment investment per farm was \$1,158.64, of which about \$240 represented the spray outfit. The equipment investment outside of the spray outfit was \$7.75 per acre.

Table II gives the average total working capital per farm, the number of horses, hogs, cattle, etc., and the average investment per farm in stock and horses. Working capital is considered to include investment in equipment, live stock, and supplies on hand.

* Spraying includes one dormant and three lead arsenate sprays.

TABLE II.—Average working capital per farm and average investment per farm in horses, stock, and poultry, and number of horses and stock (218 farms, western New York).

County.	Working capital.	Investment.		Number of head.				
		Horses.	Stock and poultry.	Horses.	Cows.	Cattle.	Sheep.	Hogs.
Wayne.....	\$3,091.31	\$945	\$518	5	4	2	8	5
Ontario.....	3,791.46	1,147	804	6	3	4	33	9
Monroe.....	3,222.78	1,150	541	6	4	3	13	5
Orleans.....	3,314.68	1,186	480	6	3	1	27	3
Niagara.....	3,069.96	1,134	376	6	3	2	2	5

TABLE III.—Principal field crops and acreage and yield of each (218 farms, western New York).

County.	Rec-ords.	Acres per farm.	Till-able area.	Acres. in fruit.	Hay.		Corn.		Wheat.		Oats.		Beans.	
					Acres.	Yield.	Acres.	Yield.	Acres.	Yield.	Acres.	Yield.	Acres.	Yield.
Wayne.....	44	103.34	Acres. 91.67	33	16	Tons 1½	8	Bu. 70	5	21	10	45	3	Bu. 18
Ontario.....	42	139.21	127.74	22	30	2	10	86	14	28	12	49	5	17
Monroe.....	47	116.03	105.59	31	17	1½	6	85	14	24	10	51	7	17
Orleans.....	50	121.10	110.57	40	19	1½	6	86	11	24	8	50	7	18
Niagara.....	35	113.24	105.66	48	17	1½	7	80	8	25	10	47	3	20

FARM ORGANIZATION.

The agricultural area of western New York is given over mainly to general farming, with orchard fruit as one of the principal sources of income. The major field crops grown are hay, winter wheat, oats, corn, beans, and potatoes (see Table III). Buckwheat, barley, and rye are minor crops. Limited areas are devoted to truck crops and small fruits.

The classification of farming is often based on the principal source of income, and for that reason many of the farms in the areas studied may be classed as "fruit farms." There is considerable variation in the intensity of this type of farming, depending to a large extent on such factors as proximity to the lake, kind of soil, size of farm, and nearness to market. These conditions govern to a great extent the amount and kind of crops or fruits grown. In Niagara County, for instance, the soil and climatic conditions are such that the growing of peaches has become one of the State's greatest farming enterprises. A large percentage of the farms considered in this county have more acres in peaches than in apples. In Wayne County there are sections that are particularly adapted to raising peaches, truck crops, and small fruits. In Ontario County 83 per cent of the tillable area of the farms studied is in field crops, while 17 per cent is in fruit,

whereas in Niagara County 55 per cent is in field crops and 45 per cent in fruit.

In this area may be found scattering 10- to 25-acre farms, with more or less small fruit or truck crops, but the diversified farms usually are from 80 to 150 acres in size. This gives opportunity to grow one or more cash field crops and feed for the work horses and a limited amount of live stock. By referring to Table IV it will be seen that the average size of farm is about 120 acres. Ninety per cent of the farm area is tillable; 68 per cent of this tillable area is devoted to the growing of crops; 32 per cent is in fruit.

TABLE IV.—Average size of farms and acreage in crops (218 farms, western New York).

	Wayne.	Ontario.	Monroe.	Orleans.	Niagara.	Five counties.
Number of farms.....	44	42	47	50	35	218
Acres in farm.....	103.34	139.21	116.03	121.10	113.24	118.65
Tillable acres in farm.....	91.67	127.74	105.59	110.57	105.66	108.20
Acres in bearing apple orchard.....	13.88	11.31	13.31	17.04	13.97	14.00
Acres in young apples and other fruit.....	19.60	10.35	17.70	22.99	33.64	20.44
Acres in other crops.....	58.19	106.08	74.58	70.54	58.05	73.76
Tillable acres per horse.....	18.54	21.26	18.83	19.77	18.36	19.38

The relative importance of the apple is shown by the fact that 13 per cent of the tillable area of the farms studied is in bearing apple orchards. There are many farms which are almost entirely given to the production of tree fruits, such as apple, peach, pear and cherry. Few of these, however, exceed 500 acres.

NEED OF MANURE.

The western New York farmer feels the need of the application of more manure to his orchards and crop lands and tries to find a way to obtain it most economically. A few men, where the farms are large enough and pasture sufficient, are keeping sheep; some pasture their orchards with sheep a part of the year. Many, to a limited extent, are in the hog business. Again, we find a few men buying cattle in Chicago or Buffalo markets for winter feeding, and selling the same in the spring or when prices seem the best. The need of manure for the orchard is perhaps the principal reason for winter feeding of cattle or sheep in this area. If a profit is made over labor, interest on investment, etc., the farmer feels that the enterprise has more than justified itself.

CROP ROTATION.

There are several practical rotations which are used in this area, depending, of course, on the crops grown. One of the most common is (1) oats, (2) wheat, (3) clover and timothy hay from one to four

years, and (4) corn. The following rotations are also found in common use throughout this area:

(1) Oats, (2) wheat, (3) clover, (4) potatoes.

(1) Oats, (2) wheat, (3) clover, (4) beans, (5) corn.

(1) Wheat or rye, (2) clover, (3) beans, (4) corn or potatoes.

Within the past few years, when weather conditions would permit, many farmers have been following what seems to be probably the most economical rotation to be used in the production of beans, namely, (1) wheat, (2) clover, (3) beans.

THE ORCHARDS.

There is great variation in the type and present condition of the older bearing apple orchards of western New York. On this account, in order to arrive at what was deemed a fair figure for cost of production, it was necessary to select for study orchards of about the same physical condition and age. This necessity eliminated from investigation many of the older orchards which had originally been set so close that every other row or tree in the row had been removed, those in which resets had been planted, and a few mixed orchards in which there were other kinds of fruit trees with the apples. The orchards selected for investigation were only those which were in every way comparable and representative of normal conditions.

Commercial orchards of the western New York district are generally well managed. The growers know the importance of constant care in order to insure fair returns over a period of years. Past experiences have taught them that neglect for a year or two may be disastrous.

SIZE OF ORCHARDS.

Orchards in this area vary from the acre or acre-and-a-half family orchard to the large commercial orchard containing 50 to 100 acres. The average for the different counties, as covered in this survey, is shown in Table III. As the farm increases in size there is a tendency toward increased acreage in fruit. Some farms are devoted almost exclusively to fruit. This condition, however, is the exception, and farms of this type were not considered in this investigation.

TABLE V.—*Classification of records, according to age of bearing apple orchard (218 farms, western New York).*

Groups.	Number of records.	Average age.
Under 20 years.....	1	18
20 to 30 years.....	36	28
30 to 40 years.....	105	37
50 to 50 years.....	64	47
50 to 60 years.....	8	56
Over 60 years.....	4	61

AGE OF TREES.

Orchards visited in this study average 40 years old. Table V shows the number of orchards of different ages. Perhaps 85 to 90 per cent of the orchards in these counties are over 20 years of age, and there are many profitable orchards over 50 years of age. The number of years that a western New York apple orchard will live and produce profitable crops has not been clearly determined. However, there is reason to believe that the average western New York apple orchard reaches its maximum yielding power when it is between 40 and 50 years of age. This, of course, depends to a very great extent on the variety of apples, the type and condition of the soil, and the kind of care which the trees receive.

TREES PER ACRE AND THE METHOD OF SETTING.

The trees in many orchards of this region are set too close, and most orchardists realize this fact. In the early days of planting many of the orchards were set 30 by 30 feet or less. Practically all of the early orchards were set on the square. Within the past few years it has been the plan to plant such standard varieties as Baldwin and Rhode Island Greenings 40 to 50 feet apart and interset these with either peaches or earlier bearing apples such as Wealthy, Gravenstein, Oldenburg, Alexander, and Twenty Ounce. When the peaches have fulfilled their mission or when the interset apples begin to interfere with the standard varieties they are removed. The apple orchards considered in this investigation averaged 35 trees per acre.

VARIETIES.

The Baldwin stands first in output among the apples grown in western New York. This variety constitutes from 50 per cent to 60 per cent of the apples grown. The Rhode Island Greening ranks second.

The apples grown here are classified commercially into summer, fall, and winter varieties. The principal summer and fall varieties are Oldenburg, Wealthy, Gravenstein, Alexander, Twenty Ounce, and Hubbardston, while the principal winter varieties are Baldwin, Rhode Island Greening, Northern Spy, Roxbury, Tompkins King, and Ben Davis. Several other varieties are grown, but these do not materially affect the commercial market.

ORCHARD INVESTMENT.

An estimate of the value of the bearing apple orchard on the farm was obtained from each farmer. The average investment per acre for the orchards here considered was about \$500. There was some little variation in the value of land. The apple orchard, how-

ever, made up about one-third of the estimated land and improvement investment.

The average investment per acre for crop land and for apple orchards was the highest in Orleans County and the lowest in Ontario.

YIELDS.

Figures on yields were obtained from each grower covering a period of six years, 1910 to 1915, inclusive. Table VI shows the average yields in barreled and culled fruit and per cent that each class is of the total yield. Considering all counties, 24 per cent of the total yield was culls, and 76 per cent, or 84 barrels per acre, was packed fruit. The packed barrel yield, as reported, is affected by the method of sorting and packing. Some growers sort and pack more closely than others, and often much of the fruit which the grower might put in a barrel would be culled by another.

TABLE VI.—*Showing barreled and cull yields per acre and per cent that each is of the total yield (218 farms, western New York, 1910-1915, inclusive).*

Counties.	Records.	Barreled yield.		Cull yield (barrels).	
		Per acre.	Per cent of total yield.	Per acre.	Per cent of total yield.
Wayne.....	44	73.2	67	36.6	33
Ontario.....	42	93.3	79	24.3	21
Monroe.....	47	85.3	78	24.0	22
Orleans.....	50	86.8	77	26.6	23
Niagara.....	35	81.4	79	22.2	21
All counties.....	218	84.1	76	26.9	24

Most of the apples were packed by the farmers themselves. Usually two or three grades were made. The apples which were not barreled were hauled either to a drier or cider mill.

There were some variations in what the individual growers considered a No. 1 or No. 2 apple. Wayne County growers show the smallest barreled yield, and the largest per cent of culls. The business of drying apples has long been established in this county and not many years ago it was the custom to dry most of the fruit. Many growers still dry much fruit which might, in other counties, appear as barreled fruit. The total yield for this county is somewhat below the average yield for the other lake counties. Ontario County is a little outside of the limits of the most intensive apple-growing belt. A few years ago a considerable amount of fruit from this county was sold in bulk. To-day a much greater percentage is packed in barrels. However, the majority of growers have not been as careful in packing as have the men in the lake counties. This was one reason for the comparatively high yield reported.

TABLE VII.—*Showing relation between size of orchard and farm (218 farms, western New York.)*

Groups by acres in orchard.	Number.	Acres.		Yield per acre.
		Farm.	Orchard.	
5 and under.....	27	84.59	4.53	<i>Barrels.</i> 95.7
5 to 10.....	67	95.15	7.92	91.9
10 to 20.....	89	118.03	15.27	72.9
Over 20.....	35	191.49	29.73	72.8

Table VII shows that there is a tendency toward higher yields per acre with the smaller orchards, and that these orchards are on the smaller farms. Men on the small farms tend to specialize in fruit growing and have the greater percentage of their acreages in fruit. In considering yields it must be remembered that although the yields of Baldwins and Rhode Island Greenings govern to a great extent the average yield for this district, there are grown on many farms the following varieties: Wealthy, Gravenstein, Alexander, Ben Davis, Twenty-Ounce, McIntosh, Tompkins King, and Hubbardston. Table VIII shows the yield by years on 218 orchards in western New York. The influence of the Baldwin apple, an alternating bearer, is evident.

TABLE VIII.—*Yields by years on orchards studied in western New York.*

Years.	Number of orchards.	Yield.
		<i>Barrels per acre.</i>
1910.....	74	81.1
1911.....	180	82.0
1912.....	212	96.2
1913.....	154	72.6
1914.....	179	104.4
1915.....	177	64.1

The net cost of production is influenced by the yield. The total net labor cost per acre grows greater as the yield increases (but not in proportion), while the net labor cost per barrel grows less. The net maintenance cost is a lower percentage of the total net labor cost on farms where an average yield is high than on those where the yield is low.

ORCHARD MANAGEMENT.

There is considerable variation in the methods of orchard soil management followed by western New York apple growers. Many factors influence these methods, among some of the more important of which are nearness to lake, type of soil, and to a great extent the

type of farming followed. The greatest factor, however, is the farmer himself. If he is what is termed a "fruit man" he may be expected to do what is necessary to maintain a profitable fruit business, but unlike many of the northwestern fruit areas, the western New York district does not have many farmers who are in a strict sense apple specialists. General farming is practiced, so that the raising of other crops often conflicts with important orchard work. The men here can not give the individual care and thought to the orchard business that the northwesterner can give. Much of the cultural work is done by hired labor. Many of the farms are worked on shares, in which case the orchard is frequently neglected, since it is very difficult to make the tenant understand the importance of careful and systematic treatment of the trees over a period of years, though if prospects indicate a large crop or the possibility of fair prices the tenant as well as the owner may cultivate and spray with care.

MAINTENANCE.

The maintenance of an orchard is the real problem in successful fruit farming. Many farmers have the foundation of a successful and highly profitable enterprise, but fail to put their best thought and energies into development and completion of nature's good work. There are many poorly cared for and unproductive orchards to-day in western New York which, with the proper care and encouragement, would produce profitable crops.

The importance of maintenance is evidenced by the single fact that it requires annually about 75 man hours and 60 horse hours per acre. This amounts to about 44 per cent of the total man labor and 68 per cent of the total horse labor used per acre in the production of the apple in western New York.

METHOD OF CULTIVATION.

Generally speaking, in western New York we have two types of orchards—those which are cultivated and those which remain in sod. Of the 218 orchardists who were considered in this study, 193, or 89 per cent, tilled their orchards each year (see Table IX). Of this number, 175 tilled their entire orchard annually. Cultivation usually begins as early in the spring as the condition of the land permits, continuing until the middle or latter part of the summer. After the last cultivation, 108 of the 175 sowed their entire orchards to some cover crop; 67 did not, but allowed the weeds to grow. A few of these men pastured their orchards late in the season. An estimate of the value of such pasture was given by the growers and a corresponding credit was allowed in arriving at the cost of production. Fourteen men tilled their orchards, but not annually; 11 left them in sod.

TABLE IX.—*Different methods of soil management (218 farms, western New York).*

Items.	Number of records.	Per cent of total records.
All farms.....	218	100
Till entire orchard annually.....	175	80
Till and cover-crop entire orchard annually.....	85	39
Orchards in sod.....	11	5

The most intensive part of the cultivation is done early in the spring, with the object of forming a dust mulch. Plowing is usually done with a 12- or 14-inch plow, the grower making a practice of plowing toward the tree row one year and away from the row the following year in order to keep the orchard level. A few men used gang plows. Four to six inches is the usual depth of plowing.

Orchard tillage is continued throughout the season as the farmer feels its need or finds time to cultivate. It sometimes happens that on account of rain it is almost impossible to make any cultivation. This, however, is not common. Ordinarily, if the orchard is well worked up in the early spring, it will be necessary to cultivate it once in 10 days or 2 weeks in order to hold the dust mulch. It was found that those who cultivated worked their orchards over an average of seven times a season.

One or more of the following implements were used after the plow: The disk harrow, roller, spring-tooth, spike-tooth, or light-draft harrow. Table X gives the average day's work, with the cost per acre for the above-mentioned implements.

METHODS OF FERTILIZING.

Closely allied with the cultural practice is that of fertilizing. One hundred and sixty-seven orchardists tilled annually and used some kind of fertilizer; 44 used barnyard manure; 60 barnyard manure and a cover crop; 38 barnyard manure, commercial fertilizer, and a cover crop; 19 barnyard manure and commercial fertilizer; and 6 a cover crop. Not all of these men, however, made such use of manure or fertilizer an annual practice.

TABLE X.—*Average time required and cost for different cultural operations in bearing apple orchards with a crew of one man and two horses (western New York).*

Implement.	Acres in 10 hours.	Cost per acre.
Walking plow.....	1.98	\$3.00
Roller.....	12.07	.45
Disk.....	7.03	.84
Spring-tooth harrow.....	9.67	.57
Spike-tooth harrow.....	11.53	.48

Orchards which were tilled annually (see Table XI) are divided into three groups—those which used (1) barnyard manure; (2)

barnyard manure and a cover crop; (3) barnyard manure, fertilizer, and a cover crop. The majority of annually tilled orchards are in one or another of the above groups. The barrel yields per acre for these groups are 85.8, 85.6, and 86.4, respectively; the maintenance costs per acre \$24.34, \$26.85, and \$28.35, respectively. The chief differences are in the time spent in pruning, cultivating, and spraying. The handling costs were about the same in each group, respectively, \$25.85, \$26.42, and \$28.74 per acre. The material and fixed costs per acre are \$76.72, \$85.37, and \$93.52, respectively. These variations in costs are due chiefly to differences in the estimated valuation of orchard land, the apple-building charge, the cost of spray material, manure, and fertilizer. The total net cost of production per acre was \$113.67, \$125.64, and \$133.47, respectively, making a net cost of \$1.33, \$1.47, and \$1.54 per barrel. With yields approximately the same and the cost of production increased by more intensive management, the net returns per acre were least from the orchards in group 3.

TABLE XI.—Average maintenance, handling, material, and fixed costs per acre for orchards, grouped according to methods of fertilizing (western New York, 1910-1915).

Items.	Group 1.— Ma- nure (44 rec- ords).	Group 2.— Ma- nure and cover (60 rec- ords).	Group 3.— Ma- nure, fertil- izer and cover (38 rec- ords).	Items.	Group 1.— Ma- nure (44 rec- ords).	Group 2.— Ma- nure and cover (60 rec- ords).	Group 3.— Ma- nure, fertiliz- er and cover (38 rec- ords).
Yield per acre (barrels)...	85.8	85.6	86.4	Material and fixed costs:			
Value apple orchard per acre.....	\$434.00	\$532.00	\$543.00	Interest.....	\$21.67	\$26.58	\$27.13
Maintenance costs:				Apple building charge.....	.51	1.66	3.31
Manuring.....	2.35	2.31	2.26	Equipment.....	3.03	3.54	3.02
Fertilizing.....			.49	Taxes.....	2.00	2.46	2.11
Pruning.....	4.99	4.54	5.51	Insurance.....	.40	.38	.49
Brush.....	2.20	1.95	2.23	Spray material.....	8.56	9.33	8.32
Plowing.....	2.82	2.73	2.64	Gas and oil.....	.51	.62	.53
Cultivating.....	4.73	5.32	4.78	Manure.....	9.84	8.51	10.67
Thinning.....	.49	1.39	1.86	Fertilizer.....			5.60
Propping.....	.67	.69	.74	Barrels.....	30.20	30.42	30.18
Miscellaneous.....	.06	.04	.10	Seed.....		1.87	2.16
Cover crop.....		.63	.65	Total material and fixed cost per acre.....	76.72	85.37	93.52
Mowing.....	.04	.09	.08	Total material and fixed cost per bar- rel.....	.89	1.00	1.08
Dormant spray.....	2.03	2.13	1.88	Total cost per acre.....	126.91	138.64	150.61
Summer spray.....	3.56	5.03	5.13	Total cost per barrel.....	1.47	1.62	1.74
Total maintenance cost per acre.....	24.34	26.85	28.35	Credits:			
Total maintenance cost per barrel.....	.28	.31	.33	Cull credit.....	13.05	12.52	16.95
Handling costs:				Pasture credit.....	.17	.48	.12
Station hauling.....	4.48	4.87	4.62	Total credit per acre.....	13.22	13.00	17.07
Other hauling.....	1.23	.61	.62	Total credit per bar- rel.....	.14	.15	.19
Picking.....	12.07	12.10	13.78	Total net cost of produc- tion per acre.....	113.69	125.64	133.54
Sorting and packing.....	6.13	7.05	7.46	Total net cost of produc- tion per barrel.....	1.33	1.47	1.55
Cull labor.....	1.94	1.79	2.26	Returns per acre.....	188.76	188.32	190.08
Total handling cost per acre.....	25.85	26.42	28.74	Net returns per acre.....	75.07	62.68	56.54
Total handling cost per barrel.....	.30	.31	.33				

The amount and frequency of manurial application is governed to a large extent by the type of farming practiced. As already stated, diversified farming is the most common type in this area. Fruit, however, is one of the chief enterprises. On account of the small number of live stock kept and the lack of other sources of supply, but a small amount of manure is available, and it was found that only 17 growers in group 1 were able to apply such fertilizer each year. The remaining men were fairly evenly divided into those who applied manure to the entire orchard every other year or to one-half, one-third, or one-fourth of their orchard each year. In group 2 somewhat similar methods were used, such as cover-cropping each year, with manure applied to the entire orchard every two years, or to one-half, one-third, or one-fourth of the orchard each year. Variations of a similar nature were also found in group 3.

The highest average yield, 104.9 barrels per acre, was for 13 orchards in group 2 that were annually manured, tilled, and sowed to a leguminous cover crop. Their net cost of production was \$143.85 per acre, or \$1.37 per barrel. Their average net returns were \$86.93 per acre, which was the largest from orchards which were annually tilled. Considering all the orchards which were annually tilled, regardless of the method of fertilizing, the maintenance cost ranged from \$20 to \$32 per acre, depending upon the intensity of cultivation and the time spent in pruning, spraying, fertilizing, and minor operations. The handling costs per acre on these orchards ranged from \$21 to \$31. The material and fixed costs ranged from \$64 to \$100 per acre. There was considerable variation in all costs considered under this heading, particularly in interest on the estimated valuation of the apple orchard, taxes, insurance, etc. The total net cost of production for these orchards ranged from \$99 to \$145 per acre, while the net returns were from \$47 to \$87 per acre.

The maintenance cost per acre for the 11 orchards in sod was \$14.80, or 19 cents per barrel. The average yield on these orchards was 77 barrels per acre. The handling cost per acre was \$21.62, or 28 cents per barrel, while the material and fixed costs were \$63.90, or 83 cents per barrel. The total net cost of production of these orchards was \$82 per acre, or \$1.06 per barrel. The net returns were \$87.62 per acre. A credit of \$5.55 per acre was allowed on these orchards as the estimated value of the use of the orchard as a pasture. In but few instances were the cultivated cover crops pastured, and such credit was small.

All the sod orchards at the time of this investigation were in good physical condition and appeared to be in as healthy a state as those which were cultivated. However, no account was taken of the amount of foliage, root growth, dead wood, condition of fruit during

the growing season, and keeping qualities of the apples, all factors of more or less importance to the commercial grower.

PRACTICE WITH MANURES.

Ninety-three per cent of the growers visited in western New York make a practice of applying farm manure to their orchards. Of these, 60, or 29 per cent, manure their entire orchard each year, and 51, or 25 per cent, manure a portion of their orchard each year, and 45, or 22 per cent, manure their entire orchard every other year.

TABLE XII.—*Influence of farm manure on yields.*

	Tons per year.		
	5 and under.	5 to 9.	Over 9.
Number of records.....	29	12	5
Tons of manure per acre.....	3.62	6.92	12.80
Yield (barrels).....	82.7	89.4	99.5

Table XII shows the influence of farm manure when used alone, regardless of method of tillage. As noted above, the apple growers of western New York often make a practice of keeping live stock solely because of the need and value of the manure as a fertilizer. Not enough stock is kept on the average farm to produce the manure necessary for crop and orchard land. A few men who are situated near small towns are able to get more or less manure from town stables; others attempt to rely on manure shipped by the carload from the stockyards at Buffalo.

The rate of application per acre varies from $2\frac{1}{2}$ to 25 tons. The larger amounts are applied where orchards are not manured each year. There is also some difference in the amounts applied annually in each county. In Ontario County, where the percentage of the farm in field crops is comparatively high and the amount of stock kept comparatively large, more manure is applied per acre than in the other counties in question. Furthermore, in the lake counties the peach, cherry, plum, and other fruits may need manure, so that there the apple orchard stands to get a smaller percentage of available manure than in Ontario County.

Green cover crops serve as a substitute for manure. Where there is a shortage of manure, some growers make a practice of using a cover for a year or two, plowing it under, working the orchard up well, and in the following year making a heavy application of barnyard manure.

Sixty-six per cent of the farmers visited use a team and one man for hauling manure to the orchard. Some men place the manure in piles throughout the orchard and spread it at a later time. A more common practice, however, is to spread the manure from the sled or wagon as it is hauled. Manure is spread some distance away from the trunks of the trees, more often between the rows. Forty of the growers used manure spreaders.

The application is made at any time during the year, most of the manure, however, being applied during the fall and winter. A bobsled seems to be a very satisfactory means of hauling.

TABLE XIII.—Average expenditure per acre in applying manure (crew, one man and two horses, with wagon or with spreader).

	Number of records.	Acres in 10 hours.	Hours.		Labor cost.	Tons per acre.	Material cost.	Total cost.
			Man.	Horse.				
With wagon :								
Wayne.....	21	1.79	8.52	17.04	\$4.26	8.74	\$15.30	\$19.56
Ontario.....	17	2.38	7.08	14.16	3.54	8.76	15.33	18.87
Monroe.....	20	2.06	7.93	15.86	3.96	9.33	16.33	20.29
Orleans.....	29	1.31	8.22	16.44	4.11	9.77	17.10	21.21
Niagara.....	20	1.36	8.70	17.40	4.35	9.90	17.32	21.67
All counties.....	107	1.72	8.13	16.26	4.06	9.35	16.36	20.42
With spreader ; All counties.....	26	2.46	5.43	10.86	2.72	8.07	14.12	16.84

Table XIII gives the average time and material required and total cost of applying manure with one man and team in the several counties. The average cost per acre for 133 orchards was \$3.81 for labor and \$15.93 for material (9 tons), or a total acre cost of \$19.74. Considering the average yield for these men, the actual cost would be 23 cents per barrel. It appears that the spreader is the more economical means of applying manure. A crew of one man and two horses with a spreader, applying 9 tons per acre, will cover nearly 2 acres in 10 hours.

COVER CROPS.

Cover crops as a source of humus and nitrogen appear to be more appreciated by the western New York fruit growers now than at any time hitherto. Since the limited amount of manure produced on the average farm in these districts is used to a large extent on crop land, the growing of cover crops and turning them under, giving a supply of humus to the soil, making more plant food available, improving the physical condition of the soil, and to some extent conserving plant food, is almost essential to the well-being of the orchards. Such practice is specially desirable on the heavy clay

soils of some sections of the Apple Belt, which, if not given proper care, become stiff, bake, and are very hard to handle.

The most commonly used leguminous cover crops in this area are red clover and vetch, while the nonleguminous crops are rye, buckwheat, oats, barley, wheat, rape, and cow-horn turnips. It is an advantage if the cover crop grown is a legume, since legumes meet both humus and nitrogen requirements.

Clover is the legume most often used. Usually from 15 to 20 pounds of seed per acre is sown. Both medium and mammoth are grown, the latter being the more popular. It has customarily been sown from July 15 to August 1, though of late growers have been sowing cover crops as early as June 15.

Hairy vetch seems to make a very suitable cover crop. When sown alone from a half bushel to a bushel of seed is used per acre. Vetch lives through the winter and for this reason serves to prevent washing and leaching due to excessive precipitation. The high price of seed is often considered an objection in the use of this cover crop.

The most popular nonleguminous cover crops grown in the orchards of this section are buckwheat and rye. Usually from one half to one and a half bushels of the former and three-fourths to two bushels of the latter are sown per acre. Buckwheat is usually sown before September 1. Rye, when used as a cover, is sown late in September or October. However, it can be sown at any time between July 15 and October 15. Rye usually makes a rapid growth, and it is necessary to get on the land with the plow very early in the spring in order to avoid difficulty in turning it under. Rape and turnips are ordinarily used in combination with other crops, generally clover, sometimes buckwheat or oats. Cover crops are used to a considerable extent thus in combination, clover usually constituting one member, together with such crops as cow-horn turnips, rape, barley, vetch, buckwheat, or oats. In combination proportionally less seed of each crop is usually sown.

It is often difficult to get a stand of a cover crop in many of the bearing orchards, owing to shade, so that many growers allow their orchards to grow up to weeds during the latter part of the summer. Many orchardists depend upon chickweed and think it nearly as valuable as any nonleguminous crop that could be used.

Within the last few years growers have been putting in their cover earlier than they used to, in order to insure a good stand before winter, and it seems to be more and more the general opinion that this should be the regular practice. The time to sow a cover crop depends upon the cover to be sown and the character of the season in which it is being used. With sufficient moisture present in the soil,

other things being equal, the seed is sown earlier than in a dry season.

One hundred and thirty-two, or 60 per cent of the growers, sowed cover crops; 85 of this number sowed the entire orchard every year; 11 every other year. The remainder sowed cover in a portion of their orchard each year, or seeded all the orchard once in two to five years, allowing the cover crop to remain down for a short period.

Forty-three of these growers used clover alone and 26 buckwheat. Forty-seven used a combination of cover crops, 36 of this number using clover as one part of the combination.

A man will usually broadcast between 15 to 20 acres in 10 hours. The average of 118 growers for sowing broadcast was 17 acres per day at a labor cost per acre of about 14 cents. After a cover crop is sown it is usually the practice to harrow it in. Where a team and man are used for this purpose the average cost per acre is about 50 cents.

PRUNING.

Pruning is done annually by 77 per cent of the growers considered in this investigation; 60 per cent prune their entire orchards each year.

Pruning is usually done during the winter or early spring months before any tree growth has taken place. Growers who prune each year usually follow an open-head system on the winter varieties such as Baldwin, Rhode Island Greening, and Tompkins King. Ways of pruning differ slightly with each variety, and each tree presents a problem of its own. With most varieties annual pruning means the general thinning-out of the tree, all dead wood and interfering limbs being removed. The Twenty-Ounce and Northern Spy are handled differently on account of the nature of their growth. The Twenty-Ounce is not pruned with the open head because of danger of sun scald of the main limbs, which is often followed by the New York tree canker, which kills the main limbs, and eventually the tree. The Northern Spy is usually allowed to take its own course with little or no pruning.

There are some differences in pruning practice among the several counties. About 70 per cent of the growers in Wayne and Ontario Counties pruned their entire orchards each year, while in Orleans and Niagara Counties less than 50 per cent followed this practice. This difference may be due partly to the fact that the latter growers have other tree fruits (Table IV) that require their attention, such as the peach, pear, and cherry. Many believe that pruning every other year reduces the annual wood growth and is the better method.

TABLE XIV.—Average time and cost for pruning 218 orchards, western New York, 1910-1915.

County.	Number of records.	Acres in orchard.	Trees per acre.	Age.	Trees in 10 hours.	Man hours.	Cost.		
							Per acre.	Per tree.	Per barrel.
Wayne.....	44	13.88	35	36	14	32.05	\$6.41	\$0.1831	\$0.0876
Ontario.....	42	11.31	33	36	12	33.81	6.76	.2048	.0725
Monroe.....	47	13.31	36	41	16	28.22	5.64	.1567	.0661
Orleans.....	50	17.04	34	44	14	30.41	6.08	.1788	.0700
Niagara.....	35	13.97	37	39	11	36.18	7.24	.1957	.0889
All counties.....	218	14.00	35	40	14	31.85	6.37	.1820	.0757

Table XIV shows a summary of average expenditures for pruning, with tree and barrel costs. A man will prune, on an average, 14 trees in 10 hours, making an acre cost of \$6.37, a tree cost of \$0.182, and a barrel cost of \$0.0757. The annual pro rata pruning cost per acre is \$4.85, or 20 per cent of the total net maintenance cost, or 4 per cent of the total net cost of production.

TABLE XV.—Average pruning cost for different commercial apple-growing areas.

Locality.	Number of orchard.	Age of trees.	Trees per acre.	Trees in 10 hours.	Hours per acre.	Cost.	
						Per acre.	Per tree.
Western New York.....	218	40	35	14	31.85	\$6.37	\$0.182
Wenatchee Valley, Wash. ¹	87	11	81	19	40.31	10.08	.124
Yakima Valley, Wash. ²	120	13	74	14	52.55	13.14	.179
Hood River Valley, Oreg. ³	54	12	72	30	24.36	5.48	.076
Western Colorado ⁴	125	17	74	14	53.67	18.78	.254

¹ Dept. Bul. 446.² Dept. Bul. 614.³ Dept. Bul. 518.⁴ Dept. Bul. 500.

Table XV gives a comparison of the number of trees pruned per day and the cost per acre in western New York and four other apple-growing areas, Wenatchee Valley and Yakima Valley, Wash., Hood River Valley, Oreg., and western Colorado. It should be borne in mind that in these areas there are different varieties and conditions, and the trees are considerably younger and also are set very much closer together than in New York.

Summer pruning is not practiced by the growers in western New York. Past experience has taught them that it is not practical. Many of the growers make a practice of pruning a portion of their orchards each year; some prune heavily one year and lightly the next. The size of the orchard seemingly has little effect on the time required for pruning.

BRUSH DISPOSAL.

There are several methods of cleaning up brush. Ordinarily where large limbs are removed, the finer brush is cut from them and the larger pieces used for firewood. Practically all other brush is burned in the orchard. Often there are vacancies where one or more trees have been removed at some time, and this allows sufficient space for burning. The growers use either sleds or low truck wagons for hauling brush. Crews of one, two, or three men are used for loading. Many growers use on the sled a large rack, which can be turned over easily to dump the brush on the fire. It is not unusual to find a grower using one or two 12- or 15-foot poles held 3 to 4 feet apart by 2 by 2 strips, and drawn by a team. This device serves as a rake, the brush gradually collecting across the poles. When a load is gathered it is drawn to the fire and dumped.

Often it is impossible to burn the wood early in the spring, in which case it is placed in piles at convenient places until dry. Some men make a practice of placing the trimmed wood in piles close to the trees as they prune, so that it will be easy to collect at the time that the brush is burned. A few men have homemade brush burners.

Ninety-two of the growers, or 42 per cent, use a crew of two men and two horses, and 54, or 25 per cent, use a crew of three men and two horses in disposing of the brush.

Niagara County shows the highest acre charge (\$3.34), and Monroe County the lowest (\$2.50), making a cost per barrel, respectively, of 4 and 3 cents.

THINNING.

Thinning is not an annual practice with the majority of apple growers in western New York. A few men do a little every year. Generally speaking, thinning is practiced by commercial apple growers only during the season of large crops or of aphid infestation. Since the western New York apple grower is to a great extent a producer of field crops and fruits other than apples, much of his time is necessarily taken up with general farm work, so that, however anxious he might be to produce a fancier apple than he is now giving the public, he is somewhat handicapped in this regard by the demands of other equally important enterprises. There are in each county and community, however, fruit men who devote the greater part of their time and energies to the production of the apple.

Very few of the apples on trees of the age considered in this bulletin can be thinned from the ground or stepladder, and thus thinning here presents a difficulty unknown in the Northwest. The use of an 18- to 25-foot ladder is necessary in most orchards. When it is considered that in a season of large crops the trees yield from

5 to 20 barrels and often more, the amount of labor necessary to do thorough thinning is obvious. The average grower removes a considerable amount of overabundant and aphid apples and depends upon props to hold up the remaining crop and keep the limbs from breaking. In the case of the younger bearing orchards thinning is more common than with the old orchards, the trees being smaller and the labor difficulties not so great.

Thinning does not seem to affect the quantity or regularity of apple production, although where trees bear well the fruit remaining on trees may be thus increased in size and color.

Probably, if other farm work did not interfere, more thinning would be done; however, only 19 per cent of the growers considered in this investigation followed this practice. The actual cost was \$4.63 per acre or \$0.05 per marketable barrel. The labor required for this work was 23 hours per acre.

PROPPING.

Propping is governed to a great extent by the amount and method of pruning, by the size of the apple crop, and the thoroughness with which thinning is done. Propping is a more common practice than thinning among the growers throughout western New York, being reported by little over 50 per cent of the men considered in this study.

Board props 1 by 2 or 1 by 3 inches and of lengths varying from 8 to 15 feet are very often used. It is not uncommon to see rails formerly used in an old-fashioned worm fence serving as first-class props. The actual cost for this operation was about \$1.40 per acre, or 4 cents per tree.

SPRAYING.

Spraying was introduced into New York State about 1890, just after apple scab and insect pests became so prevalent in western New York that it looked as if the apple business were doomed. Bordeaux mixture was the fungicide first used and Paris green the insecticide. About 1900 lime-sulphur began to replace the Bordeaux mixture. Up to this time Bordeaux had caused considerable damage at different times by russetting the fruit. With the introduction of lime-sulphur this, to a great extent, was eliminated, though under certain weather conditions a heavy application of lime-sulphur, either commercial or homemade, is more or less dangerous. Bordeaux mixture, either the Bordeaux paste or similar mixtures containing a different percentage of copper sulphate, and sold under trade names, is still used by a few growers. Lead arsenate, both in paste and powder, is used as an insecticide. Tobacco extract has been used and is gaining favor among the growers because of its success in the control of sucking insects.

Spraying is perhaps the most important of all maintenance labor. Practically all orchardists in the five counties in which this investigation was made do some spraying each year. From three to six applications per season are made by the commercial growers. The importance of this operation is shown by the bare fact that the labor cost is \$6.80 per acre and \$8.66 for material per acre, making a total of \$15.46, or 13 per cent of the total net cost of production. The tree cost for spraying is 44 cents. This, however, does not include a machine charge.

Gasoline-power sprayers are used by practically all growers. This outfit usually consists of a $2\frac{1}{2}$ to $3\frac{1}{2}$ horsepower engine, with a 100- to 300-gallon tank. The machine and tank are usually hauled on low truck wagons. Either a crew of two men and two horses, or of three men and two horses, is used in spraying. Where two men spray, one ordinarily tends the engine and sprays from the ground, while the other man drives and sprays from the top of the machine or tower. Where three men are used, one man drives, and the other two do the spraying; sometimes one of these men is in the tower. Two leads of hose, usually about 50 feet in length, with pipe or bamboo spray poles, are used. The pressure is usually from 125 to 250 pounds. Many outfits carry spray towers, for without a tower it is impossible to make a thorough spraying of the tops of some trees.

Within the last year or two a new type of outfit, with considerably more power than that of the old type, has been put on the market. Many fruit growers believe that this system will revolutionize spraying.

Dusting with a mixture of sulphur and some form of insecticide has been tried in this part of the country experimentally, and to some extent by growers, during the last three or four years.

DORMANT SPRAY.

"Dormant spray" usually refers to spraying prior to any tree growth, during the months of March and April. However, within the last few years there has been a tendency to delay this early spray until the fruit buds begin to show the tips of the first leaves, or even as late as when the leaves are one-fourth to one-half inch in length. This spray is termed "delayed dormant" or "semidormant." At the time of this investigation no particular distinction was drawn between the growers who made a dormant and those who made a delayed dormant spray. The delayed dormant spray is perhaps the one most generally used. The exact time of application, of course, will vary with the season; it is ordinarily applied during the latter part of April or early in May. Two hundred and six orchardists, or 94 per cent of the total number considered in this investigation, applied the dormant spray. Lime-sulphur, 32° Baumé, strength, 1 gallon to 8

or 12 of water, is generally used, though if San Jose scale is not present this spray is often applied 1 to 40. For the control of chewing insects many growers add to this solution from 4 to 6 pounds of lead arsenate to 100 gallons of material. Tobacco extract is often added, about three-fourths of a pint to 100 gallons of solution, to control aphids. An effort is made to cover the entire tree thoroughly with spray material. The delayed dormant spray is applied for the control of scales, blister mite, aphids, bud moth, and cigar casebearer.

PINK SPRAY.

The pink spray, as the name indicates, is applied when the apple blossoms are pink. The time of application of this spray varies to some extent with locality, owing principally to differences in distance from the lake, variety of tree, etc. Thirty per cent of the growers visited in this investigation applied this spray. Within the past few years this spray has been gaining in favor, for it usually comes at the time when the apple-scab infection may take place, and thus it serves as an effective protection against this fungus. Lime-sulphur is used, the strength varying from 1 to 35 to 1 to 50; that is, 1 gallon of 32° Baumé lime-sulphur to 35 or 50 gallons of water. To this solution lead arsenate is added. When a few aphids are beginning to appear, tobacco extract is used in the delayed dormant spray.

CALYX SPRAY.

The calyx spray is considered the most important by all apple growers. It is usually applied when from one-half to three-fourths of the petals have fallen. Two hundred and fourteen of the growers visited, or 98 per cent, applied this spray. Lime-sulphur is used 32° Baumé, strength 1 to 40, together with from 5 to 6 pounds of lead arsenate to 100 gallons of solution. This spray is primarily applied to control the codling moth. However, red bugs, leaf rollers, and green-fruit worms are often doing damage at this time, so that the commercial apple grower may also use tobacco extract with the lime-sulphur and lead arsenate. If apple scab is present, or weather conditions are favorable for an infection, the lime-sulphur acts as preventive or control spray.

FOURTH SPRAY.

The fourth spray is usually applied two or three weeks after the calyx spray. The method is similar and the material is of the same strength as for the calyx spray. The primary object is the control of the first brood of codling-moth larvæ. However, in the lake

region a great number of larvæ appear late in June and early in July. These latter larvæ cause serious losses of fruit, owing to so-called "side worm entrance." The control of this pest is extremely difficult. This spray also acts as a means of control if apple scab is present.

FIFTH AND SIXTH SPRAYS.

A fifth spray, or second codling-moth spray, is often made during the latter part of July or the 1st of August.

The sixth spray, occasionally made on late varieties, usually occurs from the middle to the latter part of August. In both of these sprays lime-sulphur, 32° Baumé, strength 1 to 40, and lead arsenate 5 to 6 pounds to 100 gallons of solution, are used.

TABLE XVI.—*Comparative labor and material costs per acre when homemade and commercial lime-sulphur solutions are used in spraying bearing orchards (western New York).*

	Number of growers making sprays.	Trees per acre.	Acres in 10 hours	Gallons.		Labor.		Cost per acre.		
				Per acre.	Per tree.	Man hours.	Horse hours.	La-bor.	Material.	Total.
Homemade solution:										
Dormant spray.....	57	36	4.41	278.97	7.75	6.68	5.84	\$2.21	\$2.67	\$4.88
Pink spray.....	22	33	4.59	308.94	9.36	6.57	5.27	2.10	2.23	4.33
Calyx spray.....	60	35	4.13	290.54	8.30	7.23	6.11	2.36	2.05	4.41
Fourth spray.....	21	35	4.36	301.34	8.61	6.74	5.72	2.21	1.96	4.17
Fifth spray.....	19	33	5.23	248.67	7.54	5.06	4.20	1.64	1.70	3.34
Sixth spray.....	21	36	3.65	283.65	8.16	7.38	6.39	2.43	2.11	4.54
Commercial solution:										
Dormant spray.....	149	34	4.28	258.80	7.61	6.21	5.46	2.06	4.41	6.47
Pink spray.....	43	35	4.03	273.48	7.81	6.60	5.73	2.18	2.38	4.56
Calyx spray.....	154	35	4.13	268.51	7.67	6.35	5.62	2.11	2.31	4.42
Fourth spray.....	42	35	3.88	266.65	7.62	6.69	6.07	2.25	2.11	4.36
Fifth spray.....	61	34	4.66	216.39	6.36	5.27	4.71	1.76	1.92	3.68
Sixth spray.....	49	35	3.89	303.25	8.66	6.71	6.08	2.25	2.56	4.81

COMMERCIAL AND HOMEMADE LIME-SULPHUR COMPARISONS.

One hundred and fifty-four orchardists, or 71 per cent of those visited, used commercial lime-sulphur, and 28 per cent used homemade lime-sulphur. (See Table XVI.) It was found that the material cost per acre was less where the homemade solution was applied, although usually more material was applied per acre. The labor cost was about the same in both cases.

It was impossible in this investigation to make a comparative study of the results from the use of the homemade and the commercial lime-sulphur. However, with equal care in preparation and application, it would seem probable that there would be little difference between homemade and commercial solutions in fungicidal value.

COMPARATIVE EFFICIENCY OF DIFFERENT-SIZED SPRAYING CREWS.

TABLE XVII.—Comparative labor and material cost per acre for spraying with different crews (35 trees per acre).

	Per cent of growers using spray.	Acres in 10 hours.	Gallons.		Labor.		Cost per acre.		
			Per acre.	Per tree.	Man hours.	Horse hours.	Labor.	Material.	Total.
2-2 crew:									
Dormant spray.....	89	3.94	283.89	8.11	6.09	6.09	\$2.13	\$4.36	\$6.49
Pink spray.....	24	3.96	327.26	9.63	6.02	6.02	2.11	2.85	4.96
*Calyx spray.....	95	3.89	292.96	8.37	6.18	6.18	2.16	2.43	4.59
Fourth spray.....	27	3.88	275.86	7.88	6.07	6.07	2.12	2.10	4.22
Fifth spray.....	34	4.48	248.81	7.32	4.88	4.88	1.71	2.11	3.82
Sixth spray.....	35	3.70	309.38	8.84	6.51	6.51	2.28	2.58	4.86
3-2 crew:									
Dormant spray.....	94	4.73	240.78	6.88	7.06	4.71	2.12	3.48	5.60
Pink spray.....	34	4.52	248.88	7.32	7.78	5.19	2.33	1.87	4.20
Calyx spray.....	95	4.50	252.38	7.21	7.66	5.11	2.30	2.01	4.31
Fourth spray.....	27	4.35	268.72	7.46	8.22	5.48	2.47	1.91	4.38
Fifth spray.....	37	5.39	185.36	5.62	5.98	3.99	1.79	1.48	3.27
Sixth spray.....	26	4.16	299.80	8.33	8.40	5.60	2.52	2.35	4.87

Prior to 1916, 50 per cent of the apple growers visited used a crew of two men and two horses for spraying, while 40 per cent used a crew of three men and two horses. (See Table XVII.) It was found that in each county the 3-man, 2-horse crew sprayed more acres per day than the 2-man, 2-horse crew. More material was applied per acre and per tree with the crew of two men and two horses than with the larger crew, and the labor costs were about the same. Thus ordinarily the 3-man, 2-horse crew is to a considerable extent the more economical.

TABLE XVIII.—Summary of annual spraying expenditures per acre (1910-1915).

	Wayne.	Ontario.	Monroe.	Orleans.	Niagara.	All counties.
Labor:						
Man hours	18.28	18.71	20.39	23.02	21.98	20.50
Horse hours	14.97	15.32	18.92	20.62	19.77	17.96
Material:						
Gallons per acre	610.14	876.67	839.62	1,005.01	997.17	863.67
Gallons per tree	17.43	26.81	23.32	29.56	26.95	24.68
Cost per acre:						
Labor	\$5.90	\$6.04	\$6.92	\$7.70	\$7.36	\$6.79
Material	5.94	8.28	8.51	10.70	9.83	8.66
Total	11.84	14.32	15.43	18.40	17.19	15.45
Cost per tree:						
Labor	.1686	.1888	.1922	.2265	.1989	.1940
Material	.1697	.2588	.2364	.3147	.2657	.2474
Total	.3383	.4476	.4286	.5412	.4646	.4414

Table XVIII gives an annual summary of the spraying expenditures per acre.

APPLYING MATERIAL WITH A "SPRAY GUN."

The "spray gun" for applying liquid material was introduced in 1916 and is now in general use among the fruit growers of western New York. The shortage of labor and introduction of dust as a fungicide and insecticide had much to do in bringing about its use.

The gun was introduced after the completion of the principal part of this study, but it has had such a marked effect on labor requirements that it has seemed advisable to show the amount of spray material applied, the time required, and the total cost of spraying with this new method. In this area practically all spray crews now consist of two men and a team. One man does the driving, the other applies the material with the gun.

Material and labor costs have advanced since 1915. Commercial lime-sulphur, which formerly cost the farmer 14 cents, now is 18 cents per gallon, while lead-arsenate paste has advanced from 8 cents to 15 cents per pound. Man and horse labor which formerly figured at 20 and 15 cents per hour, respectively, are now 30 and 20 cents per hour.

By considering Tables XVII and XIX it will be noted that, owing to the use of the gun, approximately 40 per cent less of the diluted material is now being applied per acre than formerly, thereby decreasing the hours of labor. However, owing to increased labor and material costs per unit, the total cost of spraying remains approximately the same.

There is some question in the minds of many growers whether the new method is as efficient as the old. More or less injury to foliage and fruit has resulted, and many claim the codling-moth larvæ are not as well controlled as by the old method. From observation, however, it would seem that the greatest factor in obtaining good results is the man behind the gun. Some growers think they will return to the use of the pole and nozzles for the calyx spray, and sprays that are made on the foliage later in the season.

Definite conclusion as to the superiority of this new method over the one formerly used can not be drawn until the gun has been in use for a longer period.

TABLE XIX.—*Labor and material cost per acre (35 trees) for spraying with a crew of two men and two horses, with the use of a spray gun (1919).*

	Per cent of growers making spray.	Acres in 10 hours.	Gallons.		Hours per acre.		Cost per acre.		
			Per acre.	Per tree.	Man.	Horse.	Labor.	Material.	Total.
Delayed dormant spray.....	71	5.7	176	5	3.8	3.8	\$1.90	\$4.80	\$6.70
Pink spray.....	69	5.5	189	6	3.9	3.9	1.95	2.80	4.75
Calyx spray.....	100	5.3	192	6	4.0	4.0	2.00	2.81	4.81
Two-week spray.....	72	5.8	185	6	3.6	3.6	1.80	2.63	4.43
Aug. 1 spray.....	33	5.2	171	5	3.9	3.9	1.95	2.72	4.67

TOTAL MAINTENANCE COST.

The total maintenance cost for the 218 farms was \$24.75 per acre, or 29 cents per barrel. Deducting a credit for the use of the orchard as pasture, there is left a net cost of \$24.04 per acre. This is about 20 per cent of the total net cost of production.

HANDLING THE CROP.

Handling the apple crop consists of picking, packing (whether in orchard or packing shed), hauling empty barrels to orchard and packed barrels to shipping point or storage, and all necessary labor in handling the cull apples.

There is considerable variation in the time required for handling the crop, according to method of management, distance the crop is hauled, and yield.

The handling of the average crop in the orchards required about 100 man hours and 30 horse hours per acre. This constitutes approximately 56 per cent of the total man hours and 32 per cent of the total horse hours required per year in the production of an acre of apples in western New York.

PICKING.

Picking apples by hand was practiced by 209 of the growers considered in this investigation, or 96 per cent. Nine orchardists in Wayne County shook their apples from the tree. Picking of the fall varieties usually begins with the Oldenburg about the middle or latter part of August, while the work on winter varieties usually begins with Rhode Island Greening about September 15. This is followed by the Tompkins King, which is generally picked about October 1; then come in order the Roxbury, Baldwin, Ben Davis, and Northern Spy.

One picking is usually made for each of the varieties grown in this area, except the Oldenburg, of which it is not uncommon to make from two to four pickings, sorting for size and color. Occasionally fruit of the other varieties does not ripen regularly and it is necessary to pick for size and color.

As the Baldwin and Rhode Island Greening are the principal varieties grown, this discussion will be confined chiefly to them. Since a large percentage of these varieties is stored in common storage or cold storage, they are usually picked before they are mature. Picking the Rhode Island Greening is usually begun when the seeds of the apple are beginning to turn brown, regardless of the size or color of the fruit. Ordinarily particular care is taken as to the time of picking and condition of this variety because of its tendency to scald in storage if not properly handled.

Men, women, and boys are employed at harvest. Men generally do most of the picking. The half-bushel basket, 3-peck basket, or

canvas picking bag is used. Picking ladders vary from 20 to 30 feet in length.

Day labor is figured at \$2 per day, or 20 cents per hour. Contract pickers, or those working at a stipulated rate per barrel, receive from 10 to 15 cents per barrel, depending upon the season and type of worker. The usual price is 12½ cents per barrel with board and 15 cents per barrel without board.

When the crop is large, probably more apples are picked by the barrel than by the day. In small-crop years the fruit is sparsely distributed and the pickers do not care to work by the barrel, since often it is hard to make a fair wage.

Picking by the barrel also necessitates an extra handling of the fruit, which many growers consider undesirable. However, many men who have had the same pickers season after season find it is an advantage to have their fruit picked by the barrel, for when the crop is large considerable money may often be saved by getting the fruit picked when in the proper condition and taken directly to storage.

Prior to 1917 many of the growers in western New York depended upon transient labor for pickers. Where orchards were not far from the larger cities help could be easily obtained.

Of the growers here considered, 123, or 56 per cent, had their apples picked by the day, while 86, or 40 per cent, had their apples picked by the barrel. In getting estimates the grower was asked to give the average number of barrels per day that the day or contract picker would pick with a light crop and with a heavy crop, and an average of these two estimates was taken for each record. The day laborer picked on an average 20 loose barrels in 10 hours, while the contract laborer picked on an average 25 loose barrels in 10 hours.

TABLE XX.—*Number of barrels picked in 10 hours and cost per acre and per graded barrel.*

Counties.	Day pickers.					Contract pickers.					All picking.				
	Records.	Ungraded barrels in 10 hours.	Man hours.	Cost.		Records.	Ungraded barrels in 10 hours.	Man hours.	Cost.		Records.	Ungraded barrels in 10 hours.	Man hours.	Cost.	
				Per acre.	Per barrel.				Per acre.	Per barrel.				Per acre.	Per barrel.
Wayne.....	19	20	50.49	\$10.10	\$0.1472	16	26	40.42	\$15.11	\$0.1910	35	23	45.89	\$12.39	\$0.1688
Ontario.....	30	20	58.20	11.64	.1207	6	21	42.67	13.11	.1760	42	20	55.98	11.85	.1270
Monroe.....	18	18	55.98	11.20	.1449	29	25	42.96	15.46	.1712	47	22	48.17	13.82	.1620
Orleans.....	24	21	45.11	9.02	.1059	26	26	41.69	15.61	.1768	51	25	43.33	12.45	.1434
Niagara.....	26	19	58.12	11.62	.1388	9	25	36.67	13.41	.1795	35	20	52.61	12.08	.1484
All counties....	123	20	54.11	10.82	.1282	86	25	41.39	15.06	.1774	209	22	48.95	12.57	.1486

^a Nine men in Wayne County shake their apples from the tree.

There is considerable variation in the number of barrels picked per day by both day and contract workers. (See Table XX.) Men paid by the barrel pick between 30 and 40 barrels per day during heavy crop years. With exceptionally large crops, some men will pick as high as 50 to 60 barrels per day. The rate of picking will vary to a great extent with size of crop and of trees, distance trees are planted apart, mode of tree growth, and kind of ladders and picking utensils which the picker is required to use.

When apples are picked by the day, the picker carries his apples to the sorting table, which is usually placed in a central position, so that all pickers carry their fruit about the same distance. Often when contract picking is done the barrels are placed near the trees from which the fruit is picked. Apples are placed in these barrels by the picker, who marks his barrels as they are filled or has his tally card punched by the foreman.

The average cost for picking by the day was \$10.82 per acre (yield 84.4 barrels per acre) or 13 cents per barrel, while a contract picker picked at a cost of \$15.06 per acre (yield 84.9 barrels per acre) or 18 cents per barrel. The average cost, considering both methods of picking, was \$12.57 per acre, or 15 cents per barrel. All labor in harvesting, except contract labor, is figured at 20 cents per hour. The picking cost was about 33 per cent of the total net labor cost, or 10 per cent of the total net cost of production.

It will be seen (Table XIX) that in Ontario and Niagara Counties the majority of growers visited picked their apples with day labor. In Wayne County there is a tendency toward day pickers, while in Monroe and Orleans Counties the growers depend to a great extent on contract pickers.

SORTING AND PACKING.

Sorting and packing are done in the orchard, barn, or packing shed (see figs. 6 and 7). Practically all apples are sorted and packed from a sorting table. The common sorting table is usually 8 feet in length and 3 feet in width, inside measurement. Some growers use a level table, from which all apples are hand sorted into baskets and then packed in barrels.

As soon as the apples are picked in one section of the orchard the sorting table is moved to another. Many of the orchardists who pack in the orchard make a practice of hauling a few apples into a shed or barn, so that in case of unfavorable weather the packing will not be delayed.

Prior to the passage of the New York State packing law apples were packed either "orchard run," "number ones," or "number twos." "Orchard-run" apples took in all sizes of apples above a minimum which might be stated by the buyer. "No. 1" apples

were $2\frac{1}{2}$ inches and over in diameter and practically free from scale, bruises, or blemishes. "No. 2" were apples which were below this



FIG. 6.—Picking, sorting, and packing apples in a western New York orchard.

size and of a fair quality. In those days the pack depended mostly upon the farmer himself, or, if the apples had been sold to a buyer,



FIG. 7.—Delivering apples in bushel baskets to packing shed, where they are sized on a mechanical sizer.

upon his specific directions as to the pack he desired. Often the buyer furnished a packer to insure proper grading. Many times

apples were run into the barrel just as they came from the orchard, covered with burlap, and taken directly to the storage, there to be repacked when ready for market, according to the size and quality which the buyer might designate.

Under the State law now in force the standard grades or classes for apples grown in this State when packed in closed packages are as follows: (1) New York Standard Fancy Pack; (2) New York Standard A Grade; (3) New York Standard B Grade; (4) New York Standard C Grade; (5) Unclassified. The minimum size of fruit in all these classes, including the unclassified, is determined

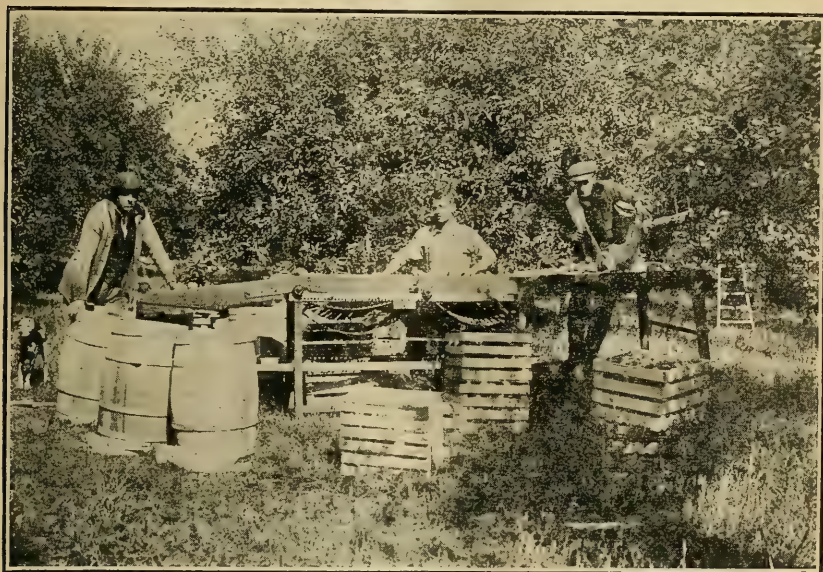


FIG. 8.—A type of sizer used by many apple orchardists in western New York.

by taking the transverse diameter of the smallest fruit in the package at right angles to the stem axis. The minimum sizes are to be stated in variations of one-fourth inch, 2 inches, $2\frac{1}{4}$ inches, $2\frac{1}{2}$ inches, $2\frac{3}{4}$ inches, 3 inches, $3\frac{1}{4}$ inches, and so on, in accordance with the facts.

It is believed by many that the quantity of marketable fruit produced in New York will not be curtailed by this law and that its enforcement will prove of great benefit to the apple growers of the State.

At the time of this investigation the majority of growers visited sorted and packed by hand in the orchard, though there was a growing tendency toward packing in the packing shed or barn. Many of the growers were considering buying sizers (see fig. 8). The average grower has so small an acreage of summer or fall fruit that the majority of it is still hand sorted and packed. The sizer is

used to a great extent on the winter varieties, principally the Rhode Island Greening and Baldwin. No doubt within a few years the majority of commercial apple growers in these counties will be using mechanical sizers and packing a considerable amount of their fruit in the packing shed or barn or in community packing houses.

By referring to Table XXI, it will be seen that the growers of Orleans County sorted and packed their fruit most cheaply, while the average cost for these operations was greatest in Ontario County. Considering 188 growers who sorted and packed their own fruit, regardless of whether or not they used sizers, it required on an average 36.72 man hours for sorting and packing an acre of fruit. The total cost per acre for sorting and packing was \$7.35, or 9 cents per barrel.

TABLE XXI.—Average time and cost per acre for sorting and packing (western New York, 1910-1915).

Counties.	Sorting and packing.				
	Number of records.	Barrels in 10 hours.	Man hours.	Cost.	
				Per acre.	Per barrel.
Wayne.....	32	29	31.10	\$6.22	\$0.0856
Ontario.....	34	25	46.18	9.24	.0981
Monroe.....	38	25	39.18	7.84	.0930
Orleans.....	49	28	33.30	6.70	.0771
Niagara.....	35	26	34.94	6.99	.0859
All counties.....	188	27	36.72	7.35	.0872

CULL APPLES.

The solution of the problem of the disposition of cull apples has led to the development of one of the greatest of American by-product industries. Each year large quantities of these low-grade apples are used both for drying and for making cider. It often happens that western New York growers experience severe local hail or wind storms, injuring many apples and sometimes making windfalls of thousands of bushels of what would have been first-class marketable stock. In such cases dry houses and cider mills sometimes open for business very early, so that the farmer may haul in fruit which otherwise might be wasted. If the wind is severe enough to take off any great quantity of apples during harvest, all hands employed are usually turned to picking up the fruit.

Scattered throughout the apple-producing counties of the State may be found several by-product plants (see fig. 9). A few years ago it was not uncommon for some of the growers to have drier kilns on their own farms. Apples in many instances were not picked, but

shaken from the trees and used almost exclusively for drier stock. However, since the price of barreled fruit has advanced, the practice



FIG. 9.—A small apple drier, Wayne County, N. Y.

of shaking apples from the trees has become a thing of the past. Growers seem to find it more to their liking to sell this stock rather



FIG. 10.—Delivering cider apples in bulk to the cider mill.

than dry it themselves. One often finds a farmer, however, who still dries his own stock and what other dryable fruit he is able to buy in

the immediate vicinity. The quantity of apples used for drying or cider varies from year to year. About one-third of the apples used

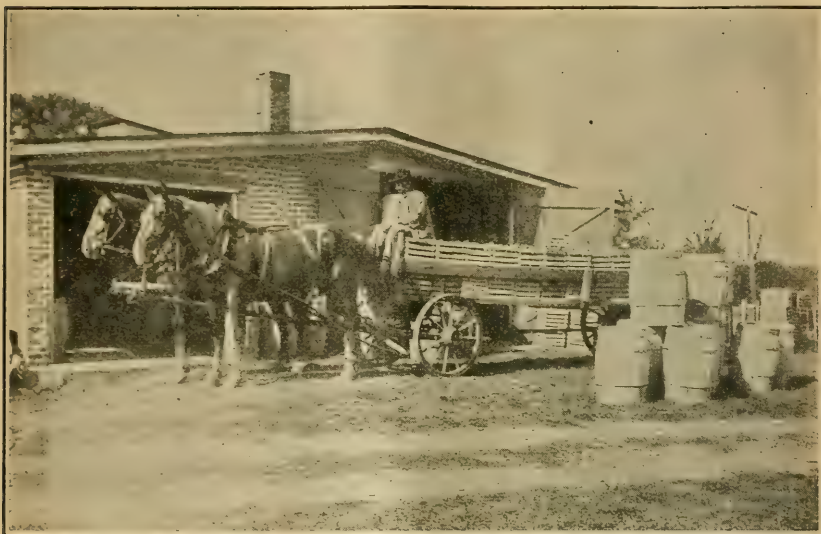


FIG. 11.—Hauling a load of about 50 bushels of cider apples in crates.

for these purposes are picked from the ground, the remainder being sorted out at packing time.



FIG. 12.—Hauling barrels, 180 to the load, from the cooper shop to the orchard.

Drier or cider apples are hauled in bulk, crates, sacks, or barrels (see figs. 10 and 11). The usual practice is to haul them in crates, delivering the apples to the factory and returning with the empty

crates. Very few of the cull apples produced in the lake counties are shipped outside of the immediate district. However, in Ontario County it is the practice of some farmers to sell this grade of fruit to a dry house at some considerable distance. This necessitates loading the apples into cars.

The price paid for cull apples varies with the season and the condition of the fruit. The market prices of the by-products control, to a great extent, the price paid for culls. Late in the season, just prior to the time of picking, or during picking, this type of dropped apple may bring anywhere from 75 cents to \$1.25 a hundredweight. When the crop is large and the price of barreled apples low, cull apples usually bring 25 to 35 cents a hundredweight. Within the last few years this grade of apple has usually brought from 50 to 75 cents per hundredweight delivered at the cider mill or drier.



FIG. 13.—Hauling empty barrels to the orchard.

Of course cider stock will not bring the price that is paid for drier stock. No separation was made of the prices received for cider and drier stock, so that the figures here presented represent average prices of drier and cider stock together. About 25 per cent of the total yield of the orchards visited was sold as drier or cider apples.

HAULING THE BARRELED FRUIT.

Apple barrels are usually delivered to the farm by the cooper or dealer, no separate charge being made for hauling (see fig. 12). The cost of hauling barrels therefore does not appear as a separate item

among those which enter into the cost of production, but is included under the cost of barrels. The barrels necessary for the crop are not usually all delivered at once, for the farmers do not ordinarily have enough storage room for them. Usually enough are delivered and stored so that the grower will have sufficient to carry him through the first few days of apple harvest. The rest of the barrels are delivered later, and are usually unloaded in the orchard.

Since some of the barrels are thus stored on the farm, it necessitates hauling them to the orchard at harvest time. This hauling is done by the farmer and is charged under "other hauling." However, farmers often haul out each morning just enough barrels to



FIG. 14.—Hauling a load of about 26 barrels to market, at a cost of about 2 cents per barrel per mile.

last until one or more loads of packed apples are hauled to the storage or shipping point, depending on the teamster returning from storage or station to drive by the barn or shed and get more barrels. (See fig. 13.)

Where apples are packed in a packing shed, some of the growers keep one man busy hauling the apples to the shed as picked. Either baskets, crates, or barrels are used for this purpose. This cost is also considered under "other hauling."

There are different methods of hauling packed apples to the storage or market; generally the regular farm wagons are used. A crew of one man and team will haul from 20 to 35 barrels per load, depending upon the outfit. (See fig. 14.) A few growers haul the

apples by auto truck. One hundred and ninety-three orchardists used teams for hauling an average of 23 packed barrels a distance of 2.26 miles at a cost of \$4.39 per acre, or about 5 cents per barrel. The average cost per barrel per mile was a little over 2 cents. (See Table XXII.)

Figure 15 shows a typical western New York apple cold-storage plant.



FIG. 15.—A typical western New York apple storage.

TABLE XXII.—Average time and cost for hauling to the station when a crew of 1 man and 2 horses is used (western New York).

County.	Number of records.	Yield per acre.	Load (barrels).	Per acre.			Cost per barrel.	Miles hauled.	Cost per barrel per mile.
				Man hours.	Horse hours.	Cost.			
Wayne	33	72.5	24	8.58	17.16	\$4.29	\$0.0592	2.68	\$0.0221
Ontario	35	90.5	22	8.06	17.92	4.48	.0495	1.82	.0272
Monroe	46	85.9	22	8.07	16.14	4.04	.0470	2.04	.0230
Orleans	46	85.8	24	8.80	17.60	4.40	.0513	2.51	.0204
Niagara	33	82.1	20	9.70	19.40	4.85	.0591	2.26	.0262
All counties	193	83.8	23	8.77	17.54	4.39	.0524	2.26	.0232

SUMMARY OF COSTS.

TOTAL HANDLING COSTS.

The total harvest labor cost for the 218 farms studied in western New York is \$26.52 per acre, or 32 cents per barrel. Deducting the value of culls, there is a net cost of \$12.06 per acre for harvesting. This is about 10 per cent of the total net cost of production. (See Table XXIII.)

TABLE XXIII.—*Summary of all labor costs (218 records, Western New York 1910-1915, inclusive).¹*

Item.	Wayne (44 records; 73.2 barrels).		Ontario (42 records; 93.3 barrels).		Monroe (47 records; 85.3 barrels).		Orleans (50 records; 86.8 barrels).	
	Cost.		Cost.		Cost.		Cost.	
	Per acre.	Per barrel.	Per acre.	Per barrel.	Per acre.	Per barrel.	Per acre.	Per barrel.
Manuring.....	\$2.11	\$0.0288	\$2.22	0.0238	\$1.76	\$0.0206	\$2.36	\$0.0272
Fertilizing.....	.40	.0055	.08	.0009	.18	.0021	.07	.0008
Pruning.....	5.40	.0738	5.92	.0634	4.15	.0486	4.00	.0461
Brush.....	2.34	.0320	2.46	.0264	1.96	.0230	1.74	.0206
Plowing.....	2.25	.0307	2.94	.0315	2.41	.0283	1.97	.0227
Other cultivating.....	4.44	.0607	4.75	.0509	4.58	.0537	3.20	.0369
Thinning.....	.99	.0135	1.44	.0154	.58	.0068	.51	.0059
Propping.....	.74	.0101	.82	.0088	.34	.0040	.86	.0099
Miscellaneous.....	.06	.0008	.22	.0024	.05	.0006	.05	.0006
Sowing cover crop.....	.11	.0015	.11	.0012	.09	.0011	.08	.0009
Harrowing cover crop.....	.30	.0041	.33	.0035	.25	.0029	.22	.0025
Mowing.....	.08	.0011	.05	.0005	.16	.0019	.13	.0015
Dormant spray.....	1.70	.0232	1.84	.0197	1.96	.0230	2.21	.0255
Summer spray.....	4.20	.0574	4.21	.0451	4.96	.0581	5.49	.0632
Total maintenance labor cost.....	25.12	.3432	27.39	.2935	23.43	.2747	22.89	.2637
Pasture credit.....	.90	.0123	1.25	.0134	.76	.0089	.53	.0061
Total net maintenance labor cost.....	24.22	.3309	26.14	.2801	22.67	.2658	22.36	.2576
Haul to station.....	3.66	.0500	5.18	.0555	4.00	.0469	4.63	.0533
Other hauling.....	1.14	.0156	.72	.0077	.57	.0067	.86	.0099
Picking.....	9.86	.1347	11.85	.1270	13.82	.1620	12.45	.1434
Shake, pick up, and haul.....	4.53	.0619						
Sort and pack.....	4.52	.0617	7.44	.0798	6.34	.0743	6.56	.0766
Pick up and haul culls.....	2.12	.0289	1.86	.0199	1.73	.0203	2.11	.0243
Total handling labor cost.....	25.83	.3528	27.05	.2899	26.46	.3102	26.61	.3065
Cull credit.....	22.68	.3098	13.57	.1454	11.30	.1325	13.44	.1548
Total net handling labor cost.....	3.15	.0430	13.48	.1445	15.16	.1777	13.17	.1517
Total net labor cost.....	27.37	.3739	39.62	.4246	37.83	.4435	35.53	.4093

Niagara (35 records;
81.4 barrels).

Five counties (218 records; 84.1 barrels).

Item.	Cost.		Cost.		Per cent of total net labor cost.	Per cent of total net cost.
	Per acre.	Per barrel.	Per acre.	Per barrel.		
Manuring.....	\$1.71	\$0.0210	\$2.05	\$0.0244	5.68	1.73
Fertilizing.....	.07	.0009	.16	.0019	.44	.13
Pruning.....	5.01	.0615	4.85	.0577	13.43	4.08
Brush.....	2.33	.0286	2.14	.0254	5.93	1.80
Plowing.....	2.54	.0312	2.40	.0285	6.65	2.02
Other cultivating.....	4.54	.0558	4.26	.0506	11.80	3.59
Thinning.....	1.08	.0133	.89	.0106	2.47	.75
Propping.....	.58	.0071	.67	.0080	1.86	.56
Miscellaneous.....	.03	.0004	.08	.0009	.22	.07
Sowing cover crop.....	.05	.0006	.09	.0011	.25	.08
Harrowing cover crop.....	.18	.0022	.26	.0031	.72	.22
Mowing.....	.05	.0006	.10	.0012	.28	.08
Dormant spray.....	2.26	.0276	1.99	.0237	5.51	1.68
Summer spray.....	5.11	.0628	4.81	.0572	13.32	4.05
Total maintenance labor cost.....	25.53	.3136	24.75	.2943	68.56	20.84
Pasture credit.....	.04	.0004	.71	.0084	1.97	.60
Total net maintenance labor cost.....	25.49	.3132	24.04	.2859	66.59	20.24
Haul to station.....	4.69	.0576	4.41	.0524	12.22	3.71
Other hauling.....	1.05	.0129	.86	.0102	2.38	.72

¹ All man labor is figured at 20 cents per hour, except some packing which is contracted at 15 cents per barrel. Horse labor is figured at 15 cents per hour.

TABLE XXIII.—*Summary of all labor costs (218 records, Western New York, 1910-1915, inclusive)*—Continued.

Item.	Niagara (35 records; 81.4 barrels).		Five counties (218 records; 84.1 barrels).			
	Cost.		Cost.		Per cent of total net labor cost.	Per cent of total net cost.
	Per acre.	Per barrel.	Per acre.	Per barrel.		
Picking.....	\$12.08	\$0.1484	\$12.05	\$0.1433	\$33.38	\$10.15
Shake, pick up, and haul.....			.92	.0109	2.55	.77
Sort and pack.....	6.99	.0859	6.34	.0754	17.56	5.34
Pick up and haul culls.....	1.82	.0223	1.94	.0231	5.37	1.63
Total handling labor cost.....	26.63	.3271	26.52	.3153	73.46	22.32
Cull credit.....	10.91	.1340	14.46	.1719	40.05	12.17
Total net handling labor cost.....	15.72	.1931	12.06	.1434	33.41	10.15
Total net labor cost.....	41.21	.5063	36.10	.4293	100.00	30.39

TOTAL LABOR COST.

The total labor cost for the 218 farms amounted to \$51.27 per acre, or 61 cents per barrel. After credit is allowed for pasture and cull apples there is a net labor cost of \$36.10 per acre, or 43 cents per barrel, which is about 30 per cent of the total net cost of production. The net maintenance cost per barrel is 29 cents, or 67 per cent of the total net labor, while the net handling cost per barrel is 14 cents, or 33 per cent of the total labor cost.

COSTS OTHER THAN LABOR.

Costs other than labor comprise material and fixed costs. The former includes the charge for barrels, spray materials, manure, fertilizer, cover crop, seed, gasoline, oil, etc. The latter includes owned equipment and building charges, spray rig hire, taxes, insurance, and interest on investment.

The average price per ton of manure is \$1.75. The average amount applied annually per acre is 4.83 tons, making the yearly cost \$8.45 per acre, or 10 cents per barrel.

Spraying materials are charged at regular prices paid, or the farmer's estimated value of the same. Commercial lime-sulphur price was given at 14 cents per gallon, while the estimated value of the homemade material was 7 cents per gallon. The majority of growers used lead arsenate paste as a poison. A few used dry lead arsenate. The prices of the former vary to some extent, but in arriving at the cost given herein an average of 8 cents per pound was used. A tobacco extract was often used at a cost of \$12.50 per gallon.

The kinds and amounts of commercial fertilizer used in the orchards of western New York varied to a considerable degree. The cost per ton varied from \$12 to \$52.

Seed for cover crops, such as mammoth clover, cow-horn turnips, rape, barley, vetch, buckwheat, etc., is charged at the market price for the same at the time of this investigation. Gasoline was figured at the rate of 25 cents per gallon, with a nominal charge for oil, etc. The price of barrels varied from 35 to 38 cents, 36 cents being the charge used. The total material cost amounted to \$49.07 per acre, or 58 cents per barrel. This is 41 per cent of the total annual net cost of production.

The fixed costs amount to \$33.61 per acre, or 40 cents per barrel, which is 28 per cent of the annual net cost of production. In these charges are certain items which are not usually considered by the grower in arriving at the cost. These items will be noted in Table XXIV. Few of the farmers of western New York have buildings which are used exclusively as packing sheds during the apple harvest. The greater part of the fruit is packed in the orchard. However, there is a tendency toward packing more fruit under cover. A few of the growers pack in their barns. This is especially the case during a rainy harvesting season. For this reason it is necessary, in determining the cost of production, to include a nominal charge for the use of buildings. This amounts to \$1.99 per acre annually, or a little over 2 cents per barrel. The equipment charge for the farms considered amounts to \$3.10 per acre, or nearly 4 cents per barrel. This includes depreciation, upkeep, and interest on the investment. But few of the growers in western New York hire spray rigs. This charge is prorated over all records so as to arrive at proper regional cost of production. Taxes amounted to \$2.30 per acre, or about 3 cents per barrel. The orchard's share of the insurance is 43 cents per acre, or \$0.005 per barrel. The interest on investment in the apple orchard is the second largest single item entering into the cost of production, making up about 22 per cent of the total net cost of production on the farms studied. This charge is figured on an average investment of \$514.35 per acre. The interest charge per acre is \$25.72, or 31 cents per barrel. The total material and fixed costs for all records is made up of about 60 per cent of material and 40 per cent fixed charges, or \$82.68 per acre and 98 cents per barrel, or about 70 per cent of the total annual net cost of production.

TABLE XXIV.—*Summary of all material and fixed costs (218 records, western New York, 1910-1915, inclusive).*

Item.	Wayne (44 records; 73.2 barrels).		Ontario (42 records; 93.3 barrels).		Monroe (47 records; 85.3 barrels).		Orleans (50 records; 86.8 barrels).	
	Cost.		Cost.		Cost.		Cost.	
	Per acre.	Per barrel.	Per acre.	Per barrel.	Per acre.	Per barrel.	Per acre.	Per barrel.
Manure.....	\$7.78	\$0.1063	\$9.52	\$0.1020	\$8.28	\$0.0971	\$9.17	\$0.1057
Fertilizer.....	4.14	.0565	.70	.0075	1.61	.0189	.68	.0078
Dormant spray material.....	2.67	.0365	3.65	.0391	3.28	.0385	4.58	.0528
Summer spray material.....	3.27	.0447	4.63	.0496	5.23	.0613	6.12	.0705
Seed.....	1.63	.0223	1.05	.0113	1.04	.0122	1.14	.0131
Gasoline and oil.....	.35	.0048	.50	.0054	.60	.0070	.71	.0082
Barrels.....	19.71	.2692	32.21	.3452	30.72	.3601	31.24	.3599
Total material cost.....	39.55	.5403	52.26	.5601	50.76	.5951	53.64	.6180
Interest.....	24.98	.3413	18.66	.2000	28.06	.3289	31.48	.3627
Apple-building charge.....	5.66	.0773	1.90	.0204	1.44	.0169	.44	.0050
Equipment charge.....	2.65	.0362	3.56	.0382	2.88	.0338	3.08	.0355
Spray rig hire.....	.13	.0018	.25	.0027				
Taxes.....	1.93	.0264	2.00	.0214	2.37	.0278	3.01	.0347
Insurance.....	.39	.0053	.27	.0029	.56	.0065	.48	.0055
Total fixed cost.....	35.74	.4883	26.64	.2856	35.31	.4139	38.49	.4434
Total material and fixed cost.....	75.29	1.0286	78.90	.8457	86.07	1.0090	92.13	1.0614

Item.	Niagara (35 records; 81.4 barrels).		Five counties (218 records; 84.1 barrels).			
	Cost.		Cost.		Per cent of total material and fixed cost.	Per cent of total net cost.
	Per acre.	Per barrel.	Per acre.	Per barrel.		
Manure.....	\$7.21	\$0.0885	\$8.45	\$0.1005	10.22	7.11
Fertilizer.....	.84	.0103	1.61	.0192	1.95	1.36
Dormant spray material.....	4.45	.0547	3.71	.0441	4.49	3.12
Summer spray material.....	5.38	.0661	4.94	.0587	5.97	4.16
Seed.....	.65	.0080	1.12	.0133	1.35	.94
Gasoline and oil.....	.64	.0079	.56	.0067	.68	.47
Barrels.....	29.29	.3598	28.68	.3410	34.69	24.15
Total material cost.....	48.46	.5953	49.07	.5835	59.35	41.31
Interest.....	23.75	.2918	25.72	.3058	31.11	21.65
Apple-building charge.....	.41	.0050	1.99	.0237	2.41	1.68
Equipment charge.....	3.42	.0420	3.10	.0369	3.75	2.61
Spray rig hire.....			.07	.0008	.08	.06
Taxes.....	2.01	.0247	2.30	.0273	2.78	1.94
Insurance.....	.43	.0053	.43	.0051	.52	.36
Total fixed cost.....	30.02	.3688	33.61	.3996	40.65	28.30
Total material and fixed cost.....	78.48	.9641	82.68	.9831	100.00	69.61

ALL COSTS.

Considering all costs, i. e., the total labor cost, the material and the fixed cost, the total net cost of production for the 218 farms was \$118.78 per acre, or an average of \$1.41 per barrel. (See table XXV.)

INFLUENCE OF YIELD PER ACRE ON COST PER BARREL.

Figure 16 shows the distribution of growers and the total number of barrels produced on the basis of the net cost per barrel. It will

be seen that 92 per cent produced apples at a cost of \$1.95 per barrel and under, while the average selling price per barrel was \$2.20. By eliminating the extremely high and low costs it is found that 85 per cent produced at from \$1.05 to \$1.95.

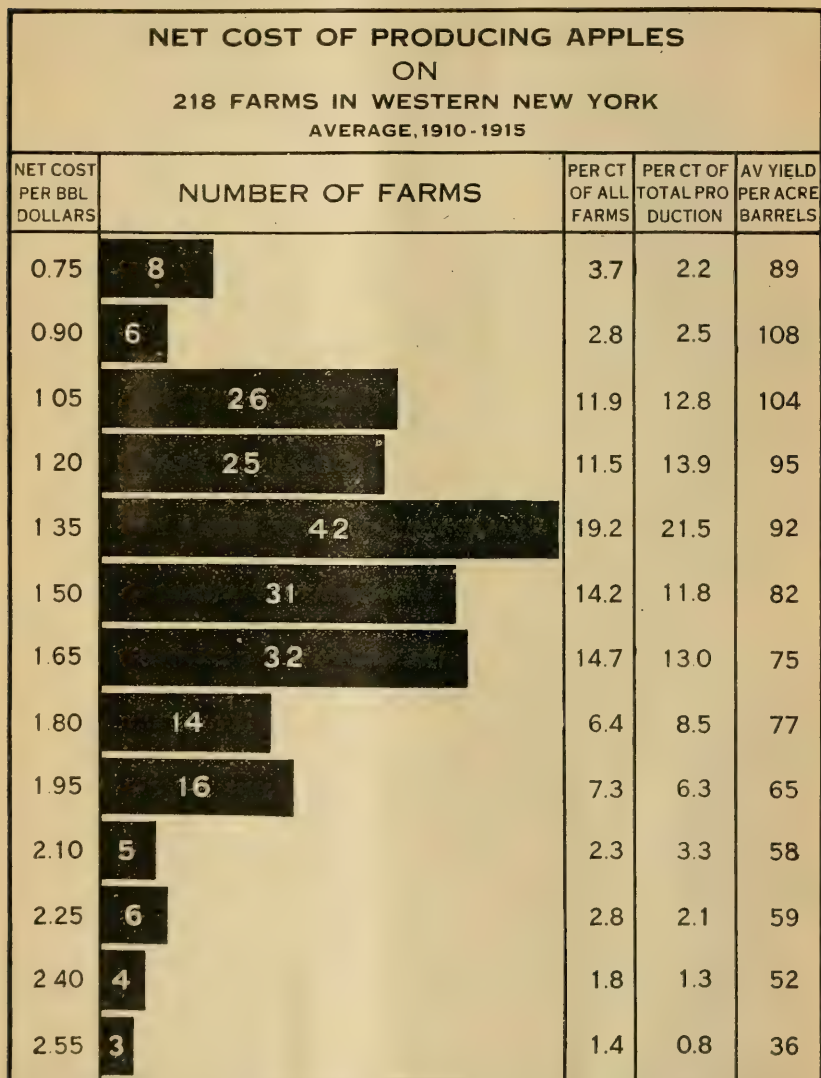


FIG. 16.—Frequency graph showing distribution of records on the basis of the net cost of production per barrel of apples. (Western New York.)

The yields for the 73 per cent range from 104 down to 65 barrels per acre, the average for the entire region being 84. Arranged on a basis of net cost per barrel, it may be shown that yields drop with fair regularity from 104 barrels in the \$1.05 group to 65

barrels in the \$1.95 group, bringing out the fact that there is a tendency toward a high cost of production as the yields decrease. However, this was not the case with every grower. To illustrate, one grower had a yield of 190 barrels per acre; the average for all records was 84 barrels. Yet the cost of production per barrel for this grower was \$1.45, or 4 cents per barrel higher than the average. By analyzing this particular record it was found that his net handling cost was 32 cents per barrel, the average for the region being only 14 cents. This difference was due to several factors. He hauled his apples eight miles to market at a cost of 9 cents more per barrel than the average grower. He did not grade his fruit as thoroughly as the average. His cull-apple credit was lower by 9 cents per barrel than the average. The cost of sorting and packing was 3 cents more per barrel, since he only put up 16 barrels per day, while the average grower packed 27 barrels.

There is a variation in the general method of orchard management throughout western New York, and a wide range in the cost of production. A high yield per acre of apples does not necessarily mean a low cost of production per barrel. However, there is a tendency for this to be the case. Generally speaking, to decrease the unit cost the yield per acre must be increased.

TABLE XXV.—*Summary of all costs (218 records, western New York, 1910-1915, inclusive).*

Item.	Wayne (44 records; 73.2 barrels).		Ontario (42 records; 93.3 barrels).		Monroe (47 records; 85.3 barrels).		Orleans (50 records; 86.8 barrels).	
	Cost.		Cost.		Cost.		Cost.	
	Per acre.	Per barrel.	Per acre.	Per barrel.	Per acre.	Per barrel.	Per acre.	Per barrel.
Total net maintenance labor cost.....	\$24.22	\$0.3309	\$26.14	\$0.2801	\$22.67	\$0.2658	\$22.36	\$0.2576
Total net handling labor cost.....	3.15	.0430	13.48	.1445	15.16	.1777	13.17	.1517
Total net labor cost.....	27.37	.3739	39.62	.4246	37.83	.4435	35.53	.4093
Total material cost.....	39.55	.5403	52.25	.5601	50.76	.5951	53.64	.6180
Total fixed cost.....	35.74	.4883	26.64	.2856	35.31	.4139	38.49	.4434
Total material and fixed costs..	75.29	1.0286	78.90	.8457	86.07	1.0090	92.13	1.0614
Total net cost.....	102.66	1.4025	118.52	1.2703	123.90	1.4525	127.66	1.4707

TABLE XXV.—*Summary of all costs (218 records, western New York, 1910-1915, inclusive)*—Continued.

Item.	Niagara (35 records; 81.4 barrels).		Five counties (218 records; 84.1 barrels).		Per cent of total net cost.
	Cost.		Cost.		
	Per acre.	Per barrel.	Per acre.	Per barrel.	
Total net maintenance labor cost	\$25. 49	\$0. 3132	\$24. 04	\$0. 2859	20. 24
Total net handling labor cost	15. 72	. 1931	12. 06	. 1434	10. 15
Total net labor cost	41. 21	. 5063	36. 10	. 4293	30. 39
Total material cost	48. 46	. 5953	49. 07	. 5835	41. 31
Total fixed cost	30. 02	. 3688	33. 61	. 3996	28. 30
Total material and fixed costs	78. 48	. 9641	82. 68	. 9831	69. 61
Total net cost	119. 69	1. 4704	118. 78	1. 4124	100. 00

PRICES RECEIVED FOR FRUIT.

Within the last few years there has been an increased demand for apples. The population has also increased to a great extent, as has the number of apples eaten per individual. With an increased demand, which has exceeded, in some years, the supply, there has been a gradual increase in the price received by farmers for the product. Some years have been very discouraging, not only because of the low price received for the product, but because of the several natural difficulties with which the grower has had to contend. Some years it has been hail, in other seasons wind, and each year must be kept up the constant fight for the control of insect pests and fungus diseases. However, the apple grower of western New York is still producing apples commercially and much of his success is due to the type of farming which has been practiced for the last fifty years.

The majority of growers in the counties considered sell their product at the time of harvest. However, there is a growing tendency toward storing. The returns received f. o. b. by the growers from whom figures were obtained averaged \$2.84 in 1910, \$2.29 in 1911, \$1.83 in 1912, \$2.80 in 1913, \$1.63 in 1914, and \$2.47 in 1915. There was some variation in the prices received for the different varieties, due not merely to differences in quality, but to a considerable degree to the ability of some growers to obtain a better price than others. This is a personal factor, and perhaps one of the chief factors of success in the cases of many of the farmers of this area.

In determining the net profit received for a product, it is usual to find the total cost and subtract from that figure the receipts from the by-product, if any. The balance is the net cost. The product in this particular instance is the marketable barreled apple. The by-prod-

ucts are the apples sold to the dryer, cannery, or cider mill. The average price received for apples by the growers considered in this investigation was \$2.20 per barrel. The average net cost of production was \$1.41. By deducting the same it will be found that the average net profit was 79 cents per barrel, with an average yield of 84 barrels per acre, or a net profit of \$66.36 per acre. If interest on investment (\$25.72) is considered as profit rather than as expense, there is a net profit of \$92.08 per acre, or 18 per cent on the investment of \$514.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 852

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Thos. H. MacDonald, Chief



Washington, D. C.

PROFESSIONAL PAPER

October 28, 1920

THE FLOW OF WATER IN CONCRETE PIPE.

By FRED C. SCOBEY, *Senior Irrigation Engineer*, with discussion by KENNETH ALLEN, ARTHUR S. BENT, F. C. FINKLE, ALLEN HAZEN, J. B. LIPPINCOTT, and H. D. NEWELL.

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INTRODUCTION.

Consequent to the general increase in use of concrete during the past 15 years, it has been but natural that this material should be tried for pipe lines; and, although there are localities where poor construction has brought concrete pipe into disfavor, where properly made it is undoubtedly a success. For a long time concrete was thought adaptable to low heads only. Now it is used extensively in this country for heads exceeding even 100 feet, and in Europe lines have been constructed to withstand pressure heads of several hundred feet. Where the heads exceed more than 15 or 20 feet the pipe is, as a rule, reinforced with steel.

The fact that it may be made at or near the place of use recom-
mends this type of construction for irrigation or other pipes far
removed from railway lines. In many cases the forms and cement

NOTE.—This bulletin treats of the subject of flowing water in concrete pipes. It is based on field tests made on pipes in commercial operation. This publication is offered for use of engineers designing and measuring concrete pipes for irrigation, power, municipal, mining, or other purposes and for courts and attorneys at law interested in cases involving the carrying capacities of concrete pipes.

are the only items requiring an extended haul. Its cost, compared with that of cast iron and steel, its permanence and comparatively fireproof qualities, are in its favor. When reinforced it is usually more costly than wood-stave pipe, and has not the required elasticity of wood or metal when subjected to a wide range of temperatures or to water hammer. Proper expansion joints will care for temperature changes.

Concrete pipe has usually been considered inferior to wood pipe in carrying capacity and the tests described in this paper confirm this belief as regards average wood pipes and average concrete pipes. These tests also show that the highest grade concrete pipe will convey slightly more water than can safely be assumed for the same size of wood-stave pipe. The results of a study of the capacity of wood-stave pipes were embodied in a previous paper.¹

While most of the experiments described in this bulletin were made on pipes under pressure, there are some tests on record which were made on flow-line pipes and conduits running to partial capacity; that is, with the surface exposed to the air. The experiments made under these two conditions will be taken up separately, in parts 1 and 2 of this paper.

NOMENCLATURE.

Unless otherwise noted, the various symbols used throughout this publication will have the following significance:

- d —The mean inside diameter of the pipe in inches.
- D —The mean inside diameter of the pipe in feet.
- r —The mean inside radius of the pipe, or $\frac{1}{2}D$, in feet.
- Q —The mean discharge of the pipe, during the test, in second-feet.
- A —The mean area of the pipe bore, in square feet, $=\pi r^2$.
- V —The mean velocity of the water, during the test, in feet per second.
- L —The length of reach tested, in feet.
- h_f —The head of elevation lost in overcoming internal resistance within a fairly straight pipe of uniform size, in feet, $=\frac{HL}{1,000}$.
- H —The above loss (termed friction loss) per 1,000 linear feet of pipe $=\frac{1,000 h_f}{L}$.
- h_v —The head of elevation lost in creating the mean velocity, V , in feet. Called velocity head.
- h'_v —The velocity head recovered as the velocity is reduced at the pipe outlet, in feet.
- h_e —The head of elevation lost at a pipe intake due to impact and entrance resistances, in feet, here called entry head.
- P —The wetted perimeter; in a pipe under pressure, the inside circumference, $=\pi D$ or $2\pi r$, in feet.
- R —The hydraulic radius $=\frac{A}{P}$; in a circular pipe, under pressure, $=\frac{D}{4}$.
- s —The hydraulic grade or slope, in feet per foot of length of a pipe of uniform size, $=\frac{h}{L}$.
- C —The coefficient of retardation in Chezy's formula.
- n —The coefficient of retardation in Kutter's formula.
- n^1 —The coefficient of retardation in Manning's formula.
- m —The coefficient of retardation in Bazin's (1897) formula.

¹ "The Flow of Water in Wood-stave Pipe," by Fred C. Scobey, Bulletin 376, U. S. Department of Agriculture.

C_w —The coefficient of retardation in the Williams-Hazen formula. (Not to be confused with C , C_m , or C_s .)

C_m —The coefficient of retardation in Moritz's formula. (Not to be confused with C , C_w , or C_s .)

C_s —The coefficient of retardation in the new formula. (Not to be confused with C , C_w , or C_m .)

f —The coefficient of retardation in the Weisbach formula. (This formula is variously known as Weisbach's, Weston's, Darcy's, and Chezy's.)

K —The coefficient of d in the general exponential formula for flow of water in pipes (formula 14, p. 45).

Cement pipe.—Composed of Portland cement and sand or fine gravel, without coarse aggregate.

Concrete pipe.—Composed of Portland cement, sand, and coarse gravel or broken stone. Will also be used as the broad term applying to both kinds of pipes for the reason that, in reality, the so-called "cement" pipe is concrete.

Number.—Wherever a pipe number is given, the reference is to the corresponding number in Tables 3, 4, and 11, and to the description of the pipe under that number.

TYPES OF PIPE.

In so far as the bounding material and other elements that influence the carrying capacity are concerned there are three distinct types of pipe, as follows:

1. Composed of an assembled length of precast units.
2. Constructed-in-place or monolithic pipe.
3. Cement-lined metal pipe.

Types 1 and 2 subdivide into three kinds:

- a. Interior surface as left by the forms.
- b. Interior surface washed with cement mortar, neat cement grout, or asphalt.
- c. Interior surface improved by troweling the joints and generally "pointing up" rough places or by rubbing down irregularities with an abrasive. (See p. 83.)

Pipes of type 1 are made with either a "dry mix" or a "wet mix." A dry mix, as its name implies, is made with a minimum of water. This permits the immediate removal of the inner and outer molds, the pipe section being cured while resting on a cast-iron base ring. This ring holds the socket end of the section true to shape, but the bevel end is generally distorted to a slight extent during the removal of the forms. The distortion is never sufficient to impair the sectional area if the inner form is true to nominal size, but all distortion is manifest in the assembled pipe line by offsets or shoulders which cause loss of head.

When tamped by hand an interior coating of cement mortar or asphalt is necessary to make pipe of this type impervious to leakage, but when the pipe is made in a machine the power tamper renders the concrete sufficiently dense without a coating to withstand the passage of water under ordinary pressure.

The cost of the many forms necessary in the manufacture of wet-mix pipe precludes the use of this method except for the highest class of work. The time of setting is greatly hastened by the use of steam. The greatest carrying capacity is attained with pipes made in this manner. One maker in California has succeeded in using a mixture so damp that coating is unnecessary, yet the forms are removed immediately, as though the pipe were made with a dry mixture. Before setting, this pipe slumps down slightly, contributing to distortion of shape and thickening of the shell. The "pull" of the forms being removed before setting leaves a rough interior surface.

Pipes made with a very wet mixture must of necessity be left in the forms until well set. Oiling or soaping the forms is necessary to prevent sticking, and makes for a smooth interior surface if the mixture is well worked when put into the forms.* Also, if the forms are rigidly true to shape, the resulting pipe is not distorted.

In the assembling of precast units there must of necessity be a joint every few feet. The standard length of small pipes is from 2 to 3 feet, while large ones are made in sections up to 8 or 10 feet long. In the early days extreme care was not taken to make smooth joints, but in present-day construction of the best workmanship on lines with pipe of such a size that a man may work inside, the joints can hardly be distinguished from the rest of the pipe, except by the color. On smaller pipes the joints are carefully wiped, so that all excess mortar is removed.

At first thought it would seem that a pipe of monolithic construction should present an unbroken surface, but in actual practice it is a difficult matter to move the forms forward so that shoulders or offsets are not formed in the pipe at the ends of the sections. (See Pl. II, fig. 2.) This is especially true on curves. These shoulders may be much improved by touching up the interior after removal of the forms, but in many cases this does not appear to have been done. In retouching, the general idea should be to avoid sudden enlargements or contractions and all shoulders should be tapered to minimize loss of head.

Wood forms are of course cheaper than steel, but the resulting surface is very inferior unless most carefully made, as any crack between the boards is clearly defined in the concrete. This may be bettered by a surface coat, but it is doubtful if any coat is as smooth as the surface first left by a well-oiled, rigid steel form, if the concrete is carefully worked into close contact at all points. Coating wooden forms with sheet metal of course gives approximately the same surface as steel forms.

PART I. FLOW IN PRESSURE PIPES.

FORMULAS FOR FLOW OF WATER IN CONCRETE PRESSURE PIPE.

Water is caused to flow and velocity created by the force of gravity. Thus the flow follows the general law of falling bodies, and the velocity tends to become constantly accelerated. This tendency is just balanced by the influences retarding the flow.

For a pipe carrying flowing water under pressure, the difference in elevation H_E (fig. 1), between the surfaces of the water at the intake and outlet is the effective head through which the force of gravity acts. The effective or lost head is made up of several individual losses as follows (fig. 1):

$$\text{Velocity head} = h_v = \frac{V^2}{2g} \quad (1)$$

This is the head absorbed in creating the mean velocity V , at which the water is conveyed through the pipe. This loss occurs at the

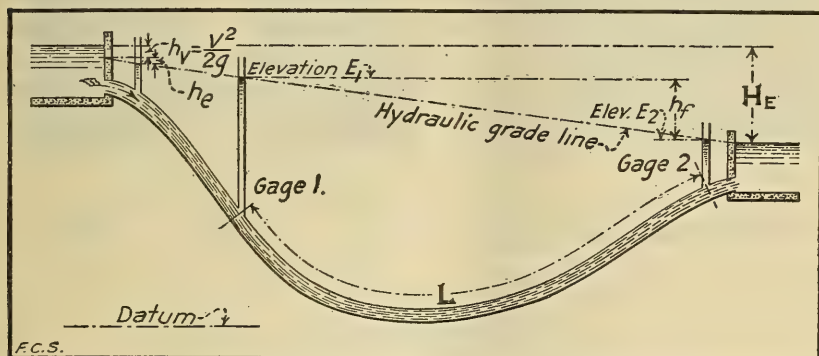


FIG. 1.—Hydraulic elements for loss of head in siphon pipe.

intake. As a rule, little or none of this velocity head is recovered at the outlet of the pipe.

$$\text{Entry head, } h_e = \frac{h_v}{2} \text{ (approximately)} \quad (2)$$

The amount of loss at the entry, due to the effect of contraction eddies and other retarding influences, is variable and uncertain, but most authorities agree that it should be taken as half the velocity head, unless the inlet structure is especially designed to minimize this loss. For further discussion see page 52.

Friction head, h_f , is that lost in overcoming the retarding influences within a reasonably straight pipe. In pipes of great length, the amount of this loss so far exceeds the two losses first mentioned that they often may be neglected, especially in small pipes. This is the loss upon which the experiments described in this paper were concentrated.

In addition to the above losses, there may be others, such as those due to bends and valves or other obstructions; but as a general thing, these items do not enter the design of concrete pipes, especially for irrigation purposes. For this purpose the pipe is laid on such gentle curves, both horizontal and vertical, that such losses need not be considered.

In 1775, Chezy, a French engineer, offered his now well-known formula for the flow of water in both open channels and closed conduits:

$$V = C\sqrt{Rs} \quad (3)$$

Here C is a coefficient, originally thought to be constant, but now known to vary with functions of the slope, the hydraulic radius, the velocity, and with some factor representing the retarding influences in the channel. Some of the formulas used in this country for the design of pipes have accepted the Chezy formula as a basis and made only such modifications as experience dictated.

Since the hydraulic elements secured in the field experiments furnish the necessary data for the determination of the factor representing the retarding influences in all the formulas most used in this country, this publication will show this factor as developed by field tests for several formulas as follows:

(a) The Chezy formula (3).

$$V = C\sqrt{Rs} = CR^{0.5}s^{0.5} \quad (4)$$

(b) The Kutter modification of the Chezy formula:¹

$$V = \left\{ \frac{\frac{1.811}{n} + 41.66 + \frac{0.00281}{s}}{1 + \left(41.66 + \frac{0.00281}{s} \right) \frac{n}{\sqrt{R}}} \right\} \sqrt{Rs} \quad (5)$$

in which C is elaborated so that it takes into consideration the influence of the hydraulic grade and of the mean hydraulic radius and introduces a new variable, n , which is supposed to represent all the retarding influences.

(c) The Weisbach formula, which has been used by textbooks as a general formula for flow of water in clean pipes:

$$h_f = f \frac{LV^2}{2Dg} \quad (6)$$

(d) The Williams-Hazen general formula² for many kinds of pipes:

$$V = C_w R^{0.63}s^{0.54} 0.001^{-0.04} \quad (7)$$

¹ E. Ganguillet and W. R. Kutter, translated by Rudolph Hering and John C. Trautwine, jr. *A General Formula for the Uniform Flow of Water in Rivers and other Channels*, New York, 1907, 2d ed.

² *Hydraulic Tables*, Williams and Hazen, 2d ed., New York, 1909, p. 1.



FIG. 1.—EXCESSIVE ROUGHNESS OBTAINED WITH POORLY MADE WOOD FORMS.

Ellipsed outlet to 60-inch round siphon pipe.

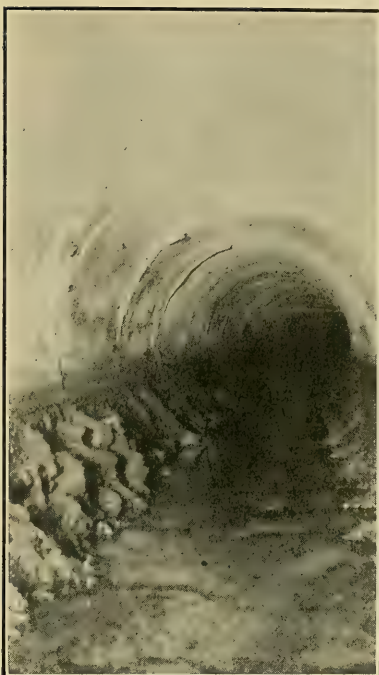


FIG. 2.—FLOW OBSTRUCTED WITH ACCRETION OF SAND AND GRAVEL, CEMENTED BY CARBONATE OF LIME.

Note "mortar squeeze" at the joints; typical of very old lines. View taken after 14 years' use.

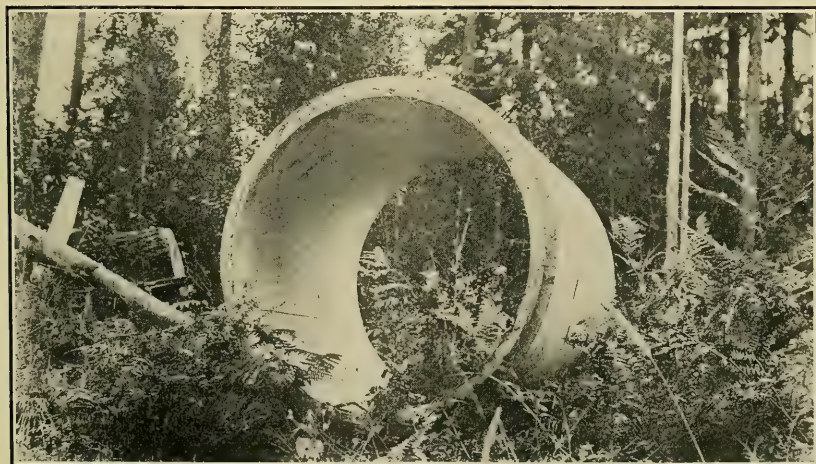


FIG. 3.—PIPE UNIT FOR VICTORIA AQUEDUCT, BRITISH COLUMBIA.

Exceeding smoothness obtained with oiled steel forms and omission of any wash coat.

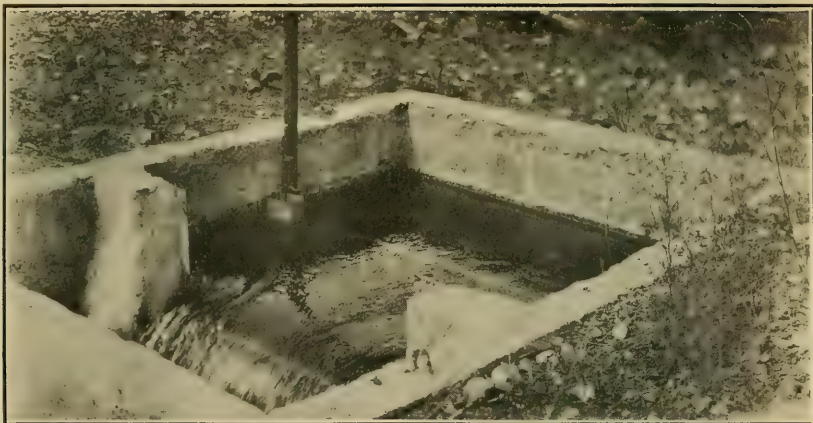


FIG. 1.—WEIR AT INTAKE OF BISHOP LATERAL, BRITISH COLUMBIA FRUITLANDS CO., KAMLOOPS, BRITISH COLUMBIA (No. 17).

Note hook gauge and stilling box.

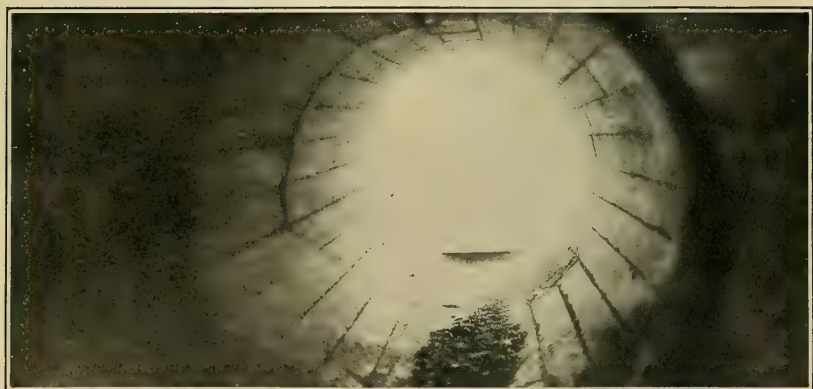


FIG. 2.—OUTLET OF CLAVEY SIPHON, OAKDALE IRRIGATION DISTRICT, CALIFORNIA.

Note ridges left by imperfect wood forms, also hardened scraps of concrete stuck to bottom, also belting ridges at ends of forms. (Pipe No. 20.)

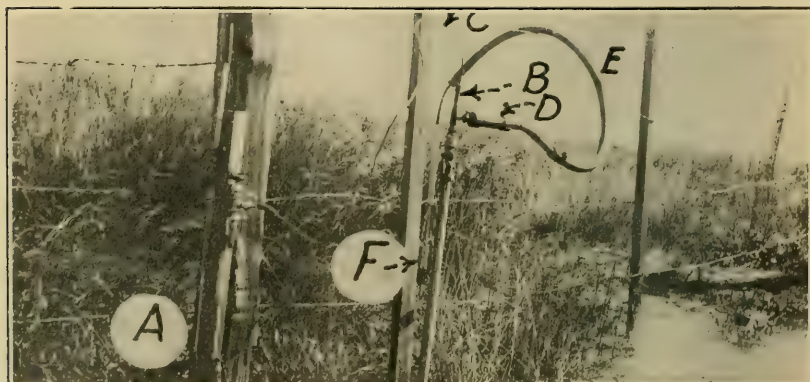


FIG. 3.—GAUGE ON D₁ LINE, UMATILLA PROJECT, U. S. RECLAMATION SERVICE, OREGON. (PIPE No. 23.)

Shows mercury manometer (A); stuffing box (B); piezometer tubing (C); color reservoir (D); color gun (E); and pump (F).

which may be arranged in the same form as formula 10, becoming

$$H = k \frac{V^{1.852}}{D^{1.167}} \quad (8)$$

The authors of the formula suggest the following values of C_w :

For masonry conduits of concrete or plaster, with very smooth surfaces, when clean, values of $C_w=140$ may be observed. Generally, such surfaces become slime covered, reducing the values of C_w to 130 or less in a moderate length of time; and if the surfaces are only a little less smooth, say in such shape as is represented by ordinarily good work, the value of C_w is reduced to 120.

It is to be remembered that at the time the above recommendation was made there were very few experimental data upon the carrying capacity of cement-plastered and concrete pipes or conduits. However, with all the data now available, the writer does not make any material difference in his recommendation given on page 64.

(e) The Moritz formula¹ for "concrete pipe built continuously with steel forms,"

$$Q = 1.31 D^{2.7} H^{0.555} \quad (9)$$

or

$$H = \frac{9.11 V^{1.8}}{D^{1.26}} = \frac{0.40 V^{1.8}}{D^{1.26}} \quad (10)$$

Moritz suggests reducing the above coefficient of 1.31 from 5 to 10 per cent for "jointed pipes, depending upon the amount of care used in producing a smooth interior surface."

(f) For the reasons set forth on pages 45 to 49 the writer offers the following formula, which differentiates between various classes of concrete pipes by means of a coefficient C_s . This formula is new to the extent of suggested coefficients only.

$$V = C_s H^{0.5} d^{0.625} \quad (11)$$

$$H = \frac{V^2}{C_s^2 d^{1.25}} \quad (11a)$$

$$Q = 0.00546 C_s d^{2.625} H^{0.5} \quad (11b)$$

in which the following values are suggested for the coefficient C_s :

Class 1. $C_s=0.267$. For old California cement pipe lines. It appears to have been the general practice throughout southern California during the early eighties to lay the pipes with a generous supply of mortar and make little or no effort to remove the "mortar squeeze" at the joints; hence these pipes, even though perfectly clean, offer great retardation to the flow of water. This coefficient is also recommended for pipes of class 2 used to convey sewage. The present practice is to wipe all joints carefully and the resulting surface approaches that of class 2.

¹ Working Data for Irrigation Engineers. By E. A. Moritz, New York, 1915, p. 66. Also see Flow of Water in Pipes, E. A. Moritz, Eng. Rec., vol. 68, No. 24, p. 667.

Class 2. $C_s = 0.310$. For modern "dry-mix" concrete pipe and monolithic concrete pipe or tunnel linings made over rough wood forms. Also for surfaces as left by cement gun process. This coefficient should be used for pipes as commonly made at the present time in the west coast States; that is, in 2-foot sections, with a dry mixture, afterwards washed with cement mortar on the inside, the work of manufacture and laying being done by contract under little or no inspection. Under favorable conditions, such as clear water to be conveyed, carefully made joints and thorough inspection, this class may be made to approach class 3, but unless sure of his conditions the designer should use class 2 (for which Table 6 has been prepared). This is especially true for pipes less than 12 inches in diameter, because of the difficulty in making smooth joints.

Class 3. $C_s = 0.345$. For small "wet-mix" pipe in short units; for "dry-mix" pipes in long units; for average monolithic pipe made on steel forms. These pipes may be evenly washed with cement mortar or asphaltum. For small cement-lined iron pipes and for concrete pipe made under pressure with interior coating of neat cement applied by a mechanical "trowel." To be used for pipes of class 4 when the water contains detritus or the line is to be used to convey sewage. (See Tables 7 and 8.)

Class 4. $C_s = 0.370$. For glazed-interior pipe lines; for large cement-lined iron pipes; for monolithic pipe lines where joint scars and all interior surface irregularities are removed. Particularly applicable to jointed lines of units made from wet, well-spaded concrete, deposited against oiled steel forms and allowed to set firmly before forms are stripped. The glazed surface resulting from this treatment is to be untouched with brush or other "wash" process and the units are to be so uniform in shape that no shoulders are perceptible to the touch when the line is finished. The finished joints are to be practically as smooth as the rest of the pipe. (See Table 9.)

This class covers only the highest grade of workmanship and materials. The specifications are rigid, but have been and can be attained commercially by an experienced organization. They are difficult to attain in a pipe less than 30 inches in diameter—too small to permit a man to work comfortably inside, and are probably prohibitive for sizes less than 12 inches in diameter. A few of the pipes upon which experiments were made appear to have coefficients higher than 0.370, but the writer wishes to be conservative in recommending a coefficient that necessitates a surface so nearly ideal. That is to say, a better surface may be attained in construction than should be anticipated in design.

All the above formulas will be taken up again after an analysis of the data, and specific recommendations made with regard to each one so that the engineer familiar with one type of formula, not desiring to change to a new one, may have the best suggestions the available data offer in terms familiar to him.

OPINIONS OF ENGINEERS REGARDING THE CARRYING CAPACITY OF CONCRETE PIPE.

Experiments upon the flow of water in concrete pipes have been so few in number that there has been developed no clearly defined trend in thought, as was the case with the capacity of wood-stave pipes.

In his discussion of tunnels, Finkle¹ advocates applying a one-fourth inch coat of cement and sand in a 1 to 2 mixture to give a smooth surface and prevent percolation through the main concrete walls. "By means of this construction," he adds, "the coefficient of roughness in the Kutter formula has been reduced as low as 0.010 and in other cases it has been as high as 0.012. If the work is very poorly done it might run to 0.013."

Schuyler states² that the conduit supplying Mexico City was designed with a value of n equal to 0.017, but upon examination after construction he remarks, "The interior of the conduit is very smooth, and answers to Kutter's rating of 0.011."

In his conclusions concerning the use of small cement-lined iron pipe, Metcalf has this to say of the carrying capacity:³

Satisfactory data are lacking upon the carrying capacity of cement-lined pipes. It is believed that under favorable conditions the coefficient of discharge to be used in the Hazen and Williams formula is about $C_w=120$, but under actual conditions this coefficient has been found, in several carefully observed cases, to lie between 95 and 110. Unless the conditions are definitely known, therefore, the use of a coefficient not exceeding $C_w=100$ to $C_w=110$ in the Hazen and Williams formula is to be recommended.

Jorgensen used a value of n of 0.012 in the design of a 6-foot reinforced concrete flow line.⁴

Conway⁵ says that n was taken as 0.013 in the design of some lines in Mexico. The pipe units were 61 cm. (practically 2 feet) long, made with a "dry mix" and afterwards coated "with a Portland cement grout to which a little freshly slaked lime was added."

TABLE 1.—Friction factors used in designing concrete pipes of United States Reclamation Service.

Project.	Line.	Type.	Size.	Kutter's used.	Length.
			<i>Inches.</i>		<i>Feet.</i>
Salt River.....	Pinto Creek.....	Continuous.....	63	0.012	2,130
Do.....	Cottonwood canyon.....	do.....	63	0.012	500
Tieton.....	Various.....	Jointed.....	6 to 30	0.013	255,689
Sunnyside.....	Mabton.....	do.....	54	0.013	3,100
Do.....	Prosser.....	do.....	30½	0.013	3,088
Umatilla.....	Various.....	do.....	12 to 47	0.013	61,728
Belle Fourche.....	Belle Fourche.....	Continuous.....	70	0.012	3,565
Milk River.....	Willow Creek.....	do.....	64	0.014	1,479
Boise.....	Chance.....	Jointed.....	30½	0.013	4,770
Do.....	Brook.....	do.....	30½	0.013	3,546
Do.....	Forest.....	do.....	36	0.013	8,575

¹ The Most Economic Type of Hydraulic Power Conduits. F. C. Finkle, Eng. Rec., vol. 52, Sept. 2, 1905, p. 263.

² The New Water-Works and Reinforced Concrete Conduit for Mexico City. J. D. Schuyler, Eng. News, vol. 55, Apr. 19, 1906, p. 435.

³ Wrought-Iron Cement Lined Water Pipe. Leonard Metcalf, Eng. News, vol. 61, p. 2, Jan. 7, 1909.

⁴ Eng. News, vol. 62, Aug. 5, 1909, p. 146.

⁵ The Water Works and Sewerage of Monterey, Mexico, by G. R. G. Conway: Trans. Amer. Soc. Civil Engin., vol. 72, 1911, p. 497.

Concerning the capacity of concrete pipes for the conveyance of sewage, Metcalf and Eddy quote from correspondence with various engineers, in substance as follows ¹ (in all cases the friction factor is Kutter's n):

J. W. Alvord uses 0.015 for concrete, but has come to the belief after completing a number of miles that he did not secure work in the Chicago district that justified much less than 0.016.

G. G. Earl uses 0.012 to 0.013 for concrete sewers in New Orleans.

G. W. Fuller uses 0.013 for concrete sewers of greater diameter than 24 inches.

J. H. Gregory uses 0.015 for concrete sewer trunk lines in the Passaic Valley.

Hardesty ² states that a value of n of 0.012 was used in designing a tunnel lining of concrete deposited against wood forms. This statement called forth a letter from C. F. Mullings ³ of the Madras Presidency, India, to the effect that orders were recently given by the Government inspector general of irrigation (India) to use a coefficient of 0.017 in the design of concrete lined tunnels.

Freeman ⁴ uses a value of n of 0.014 for concrete tunnels, stating:

This is liberal enough to cover some roughness of finish and to provide against the retarding effect of mosslike growths, such as was noted in the Boston aqueducts, and will allow for retardation by some slight deposits of sand on the bottom, although there will be small chance of this under the high velocities proposed.

Freeman goes on to state that while the linings are new and clean the value of n would probably be 0.011. For concrete-lined steel pipes he suggests a value of 0.013.

In the same report (p. 350) C. E. Grunsky uses 0.013 for a lined tunnel 10 feet in diameter.

The board of consulting engineers for the Winnipeg aqueduct makes the following recommendations: A coefficient of 132.8 (in the Chezy formula) for a concrete section of basket-handle shape, 10 feet wide and 9 feet high, with hydraulic mean radius of 2.33 feet; a coefficient of 124.1 for a section of similar shape 5 feet wide and 5 feet high with a hydraulic radius of 1.24 feet: ⁵

E. G. Hopson, in the report to the city of New York of Burr, Hering, and Freeman, ⁶ recommended a value for C , in the Chezy formula, of 128 for a concrete aqueduct, based on a diminution of $12\frac{1}{2}$ per cent on open-trench portions, due to slimes. For tunnel sections the reduction in capacity by sliming was considered as only 5 per cent, but the inferior workmanship obtained in tunnels would make the final coefficient in both cases 128.

¹ American Sewerage Practice, Metcalf and Eddy, 1st ed., New York, 1914, vol. 1, p. 97.

² W. P. Hardesty in Eng. News, vol. 56, p. 391.

³ *Id.*, vol. 57, p. 245.

⁴ Hetch Hetchy Water Supply for San Francisco, 1912, by Jno. R. Freeman, San Francisco, 1912, p. 221.

⁵ Canadian Engineer, Oct. 23, 1913, p. 605.

⁶ Report of Commission for an Additional Water Supply for the City of New York, New York, p. 214.

The board of consulting engineers¹ who reviewed the plans of the Los Angeles aqueduct suggested a coefficient for cement-lined tunnels of 0.014 for n in the Kutter formula. This value was used in the accepted design.²

After conducting a series of experiments upon both open and covered channels in southern California (see p. 88 in Appendix) J. B. Lippincott concluded:³

It would appear from these experiments that a coefficient of 0.012 for n in the Kutter formula would be safe in tunnels or covered concrete conduits with plastered surfaces.

In correspondence with the writer, under date of June 15, 1915, Mr. Lippincott writes:

An interesting feature relative to coefficients is the fact that in concrete-lined conduits in the Southwest, the effect of sunlight is very material in determining what the coefficient will be in the conduit. In the covered conduits that are dark there is no growth of vegetable or animal life in this section and our values of n are in the neighborhood of 0.010 to 0.012. If, however, the same class of lining is uncovered and exposed to the light of the sun, the coefficients are very much more unfavorable and may run up to 0.018.

RECAPITULATION.

As a broad statement, it would appear that the concrete pipes and conduits of the country have been designed by the use of the Kutter formula, and that concrete has been considered as concrete, little or no differentiation being made due to various degrees of smoothness, regardless of forms, mixtures, or surfacing, although the acquired surface, due to slimes, has been considered.

Values of n have been chosen from 0.012 up to 0.017, the reasons for this wide divergence not being quite clear in several cases. In no case has the designing engineer accepted literally the Kutter classification of 0.010 for "neat cement plaster" or 0.011 for "cement mortar one-third sand." It may be well to state here that these values of n are the only ones given in many standard lists that appear to apply to concrete and were based on very few data obtained under conditions that were probably more nearly ideal than commonly could be obtained commercially.

The Kutter formula has been particularly popular in the West, while in the Eastern States the Williams-Hazen formula is extensively used alongside that of Kutter.

A study of Tables 3 and 11 and of Plate VI will develop what coefficients may be expected from various methods of construction for varying sizes of pipe and varying velocities. While it is still evident that the Kutter formula should not be used with a given value of n for a given interior surface throughout the range of sizes

¹ This board consisted of Jno. R. Freeman, J. D. Schuyler, and F. P. Stearns.

² Construction of the Los Angeles Aqueduct, Los Angeles, Calif., 1916, p. 81.

³ Engin. News, June 6, 1907, vol. 57, p. 612.

encountered, still the change is not so marked as that found in the study of wood-stave pipes.

The Williams-Hazen formula appears to more nearly apply if the value of C_{10} is chosen as suggested on page 64.

NECESSARY FIELD DATA FOR DETERMINING THE RETARDATION ELEMENTS OF VARIOUS FORMULAS.

A glance at pages 5 to 7 shows that for study of the various formulas the same hydraulic elements must be determined by field tests. These are:

- (1) The mean velocity, V , of water in the pipe.
- (2) The loss of head, h_f , due to retardation in a section of pipe of uniform size, within a known distance.
- (3) The internal size of pipe, D or d .

The above data having been secured, the coefficient of retardation may be computed for each of the various formulas.

MEAN VELOCITY OF WATER.

The velocity of the water flowing in a reach of pipe may be measured in two general ways:

- (1) Directly, by timing a given volume of water through a known distance.
- (2) Indirectly, by measuring the discharge of the pipe, thus determining the quantity, Q , and solving the equation $V = \frac{Q}{A}$.

Where the velocity is tested by the direct method the error is probably smaller than where the indirect method is used, unless exceptional facilities for complete measurements, including interior diameters, are at hand.

LOSS OF HEAD DUE TO RETARDATION.

Most of the recent experiments on the flow of water in pipes of uniform size have been made with piezometer columns. This was the method used by the writer. If a piezometer (fig. 1) be properly attached to the pipe, the pressure in the latter will support a column of water whose surface is at elevation E_1 , on the hydraulic grade line. In the same way the pressure at gauge No. 2 will lift a column to elevation E_2 . The difference between these elevations is the head lost, h_f , due to the retarding influences.

INTERNAL SIZE OF PIPE.

The method used in ascertaining the inside cross-sectional area of the pipe is recounted in the description of each test. In some cases several joints of pipe, remaining from construction, were measured and their mean inside cross-sectional areas accepted as the internal sizes of the operated pipes. In other cases the nominal diameter of the pipe was accepted.

As made in local pipe yards along the Pacific coast, the smaller sizes of pipe, say from 6 to 20 inches in diameter, appear to run under size. The writer measured two diameters on many sections of pipe, taken at random in various pipe yards. The results may be summed up as follows:

The average true area of 8-inch pipe was 4.4 per cent less than the nominal; of 10-inch pipe was 2.7 per cent less; of 12-inch pipe was 3.5 per cent less; of 14-inch was 1.3 per cent less; of 18-inch was 1.4 per cent less. Sections of greater diameter than 20 inches appear to run quite true to nominal size.

SCOPE OF THE EXPERIMENTS.

The writer conducted 130 observations on 30 separate pipes, 29 of which ranged from 8 inches to 63½ inches in diameter and one 120 inches in diameter. Seventeen pipes were of the "dry-mix," cement-washed, jointed types; 5 were of the "wet-mix," oiled-form, uncoated jointed type; 3 were constructed in the same manner and then washed with cement; 1 was of the wet-mix, monolithic, steel-form, coated type; 3 were of the wet-mix, monolithic, wood-form, uncoated type; 1 of the same construction, coated. All but two of these pipes were "running full"; that is, under pressure. Mean velocities ranged from less than 1 foot per second to more than 9 feet per second.

From other sources also listed in summary Tables 3, 4, and 11, and briefly described in the Appendix commencing on page 77, descriptions of experiments on pipe up to 18 feet in diameter are abstracted.

EQUIPMENT AND METHODS EMPLOYED FOR COLLECTING AND INTERPRETING FIELD DATA.

With the following exceptions, the equipment and methods used were the same as those employed in the experiments on wood-stave pipe and which were described in Bulletin 376 of the department. For the sake of brevity these descriptions will not be repeated here.

Color injector.—The only practicable method of measuring the velocity of water in some of the pipes tested was by timing the passage of some color or chemical. For comparatively small volumes of clear water a saturate solution (from 5 to 8 per cent in air temperatures) of potassium permanganate was used. This color is rather uncertain, being decomposed by some waters and neutralized by reddish or muddy waters. Where certainty of results is desired, almost regardless of the water, fluorescein is the best chemical and Congo red the second choice, in the knowledge of the writer. At the present time, however, either is practically impossible to obtain.

It is desirable to start the color at a gulp, whether in water under pressure or in a pipe but partly filled. The "color gun" used in the experiments upon wood-stave pipe was improved somewhat. As shown in figure 3, *S* is a reservoir into which the solution is poured, through the coupling *W*. The latter is then closed and the air reser-

voir *X* blown up with the bicycle pump until under a pressure much in excess of that existing in the pipe under test. At a definite noted time the color is injected into the pipe through the cock *V*. The gauge readings were taken simultaneously with the passage of the color through the pipe.

Color siphon.—Where the pipe discharged into a sand or division box (Pl. III, fig. 1), the first appearance of the color could be noted easily at the pipe outlet, even though 6 or 8 feet below the surface, if the water was clear, but it was impossible to determine when the last sight of color reached the end of the pipe, as the pool would then be filled with colored water. To overcome this difficulty a length of garden hose was calibrated as a true siphon. The inlet end of this siphon was then held in the pipe outlet and the last appearance of color was observed at the outlet of the hose. From the calibration it was found that an effective head of 1 foot required four seconds to discharge a volume of water equal to the volume of the interior of the hose siphon. Thus, if the outlet of this siphon was always just 1 foot lower than the water in the outlet chamber, then the last appearance of the color in the concrete pipe was just four seconds before its last appearance at the hose outlet.

Air trap.—Since all water flowing in pipes contains more or less air in solution and sometimes even free bubbles of air, an accumulation of air in the piezometer tubes is to be looked for. In order to insure a water column free from air between the pipe and the gauge glass, the attachment shown in Plate V, figure 1, was developed. A solid water column follows the tubing *aaa* to the gauge glass, while air bubbles, taking the highest path, pass into *bb*. Any bubbles that might escape the first glass *Y* at *b* are given another opportunity to escape at *c*. The air chamber *d* is provided with an air valve. In blowing out the pressure tubing, the valve *V* is opened wide to create a draft. The air valve at the gauge glass is opened very slightly. A relatively large amount of water escapes at *V* and a small amount at the gauge glass. By watching the glass *Y* at *b* it could be seen that no bubbles passed into the tube *aaa*, thus assuring a column of solid water.

ATTACHMENT OF PIEZOMETERS.

Probably no small portion of the discrepancy between results of tests on carrying capacity of various kinds of pipe is due to the method of measuring the pressure head. Apparatus of some form must be installed so that the pressure head will sustain a water or mercury column to an elevation corresponding to the true hydraulic gradient over the point of application of the pressure. In order to secure this result, all positive or negative influence of velocity head must

be excluded. Herein lies one difficulty in making tests on concrete pipes in commercial service.

There are two general ways in which access to the stream within a pipe may be secured. A small tube like *A* or *B*, figure 4, may be thrust directly into the stream, or a connection set in the shell of the pipe, like *C*. Tubes of type *A* or *B* were smoothly tapered, with the holes passing through the opposite sides of the tube. When a connection was to be made far from the end of the concrete pipe, a hole was tapped in the latter and the tube inserted through a stuffing box. According to White¹ a tube of type *A* not only registers the proper pressure head, without velocity-head influence, in an open channel, but also within a closed pipe. His third conclusion is that Pitot tubes whose constants are unity in open canal ratings will remain unity, whatever the pressure of the liquid. His tubes *M* and *N* are of this type. Our tube of type *A* was, in essentials, the same as White's static tubes of types *M* and *N*. Although our tubes of this type were tapered with some care, Lawrence and Braunworth² showed that the taper was of little importance.

It is to be regretted that Mills³ did not continue his experiments on piezometer connections to cover tubes like *A* and *B*. He did, however, establish the fact that a connection of type *C* registers the proper pressure head.⁴

The use of an orifice in the shell of the pipe, normal to the curve—that is, of type *C*—is justified by F. P. Stearns⁵ and later by Desmond Fitzgerald.⁶

Carrying the idea still farther, Marx, Wing, and Hoskins proved that—

“When the pressure in the given cross section of the pipe everywhere exceeded that of the atmosphere an open piezometer will stand at the same height at whatever point of the cross section it be attached, and whether it communicates with the pipe at one point or several.”⁷

In each of the experiments described in this paper, regardless of the auspices under which it was conducted, but one connection was made at each end of the reach tested.

¹ The Pitot Tube: Its Formula. W. M. White, Journal Assoc. Engin. Soc., 27 (1901), p. 35.

² Trans. Amer. Soc. Civ. Engin., vol. 57, p. 273.

³ Experiments upon Piezometers Used in Hydraulic Investigations. H. F. Mills, Pro. Amer. Acad. Arts and Sci., vol. 14 (Whole Series, 1879), p. 26.

⁴ Mills concludes “that with an orifice whose edges are in the plane of the side, and passage normal thereto, the piezometric column will stand neither above nor below the surface of the stream, but will indicate the true height of the surface.” He also notes that a very slight variation of the passage from the normal causes an erroneous reading of the piezometer column; that where the orifice projects into the stream the column rises above the surface of the stream when the orifice faces upstream or is at right angles to the stream and the column does not rise to the elevation of the surface in the stream when the orifice faces down stream.

⁵ Trans. Amer. Soc. Civ. Engin., 14 (1885), p. 3.

⁶ *Id.*, 35 (1896), p. 241.

⁷ Trans. Amer. Soc. Civ. Engin., 40 (1898), p. 526.

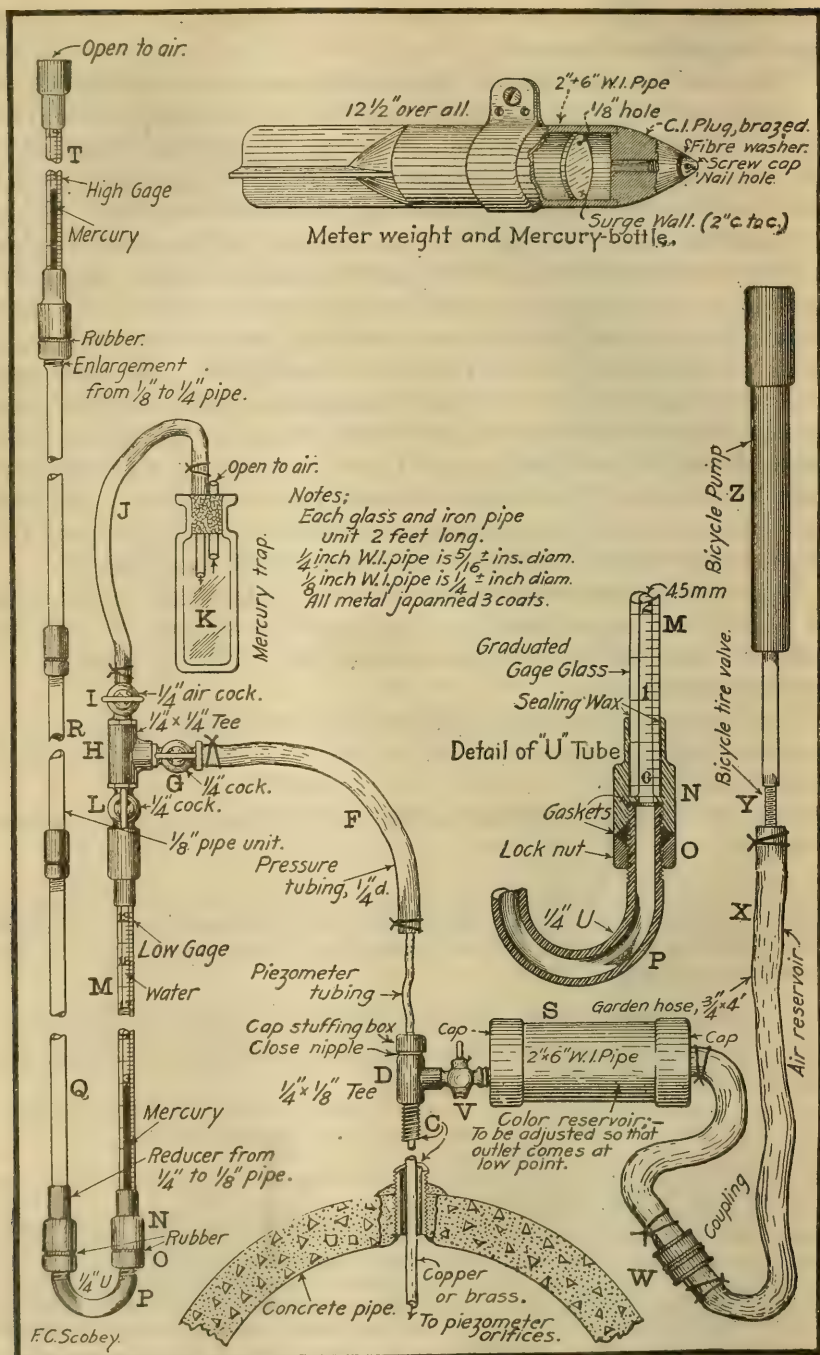


FIG. 2.—Method of attaching mercury manometers to concrete pipes. Details of manometers, fluorescein gun, and combined current meter weight and mercury bottle.

DETERMINATION OF LOST HEAD.

The exact amount of h_t (fig. 1) must be determined. Where a water column is used, say at gauge No. 2, the elevation E_2 is the gauge reading added to the elevation of the gauge zero above an assumed datum, with proper corrections (see p. 5). Where a mercury manometer of the U-tube pattern is used, the reasoning is as follows: It is desired to know the elevation E_1 (fig. 1) for a water column which is the equivalent of a mercury column in a U-tube placed as for gauge No. 1.

Referring to figure 2, the mercury in the two legs of the U-tube below Q will be seen to balance. Therefore the pressure of the water at Q is just balanced by the column of mercury

QT. But the pressure at c equals that at d . If the mercury X were replaced with water it would reach an elevation sR above Q, where s is the specific gravity of the particular mercury in the gauge, compared with the particular water in the pipe. But the elevation to which this water column would reach is the desired elevation, E_1 . As applied to these experiments, referring to figures 1 and 2, the difference in elevation between the readings of the low gauge and the high gauge multiplied by the specific gravity of the mercury and added to the elevation of the low-gauge readings gave the elevation of the equivalent water column when the proper corrections had been applied.

MEASUREMENT OF MEAN VELOCITY.

As a rule, each pipe tested presented its own problem as to the method to be adopted to determine the mean velocity of the water, and in case this method digressed from one of the following standard methods it is described.

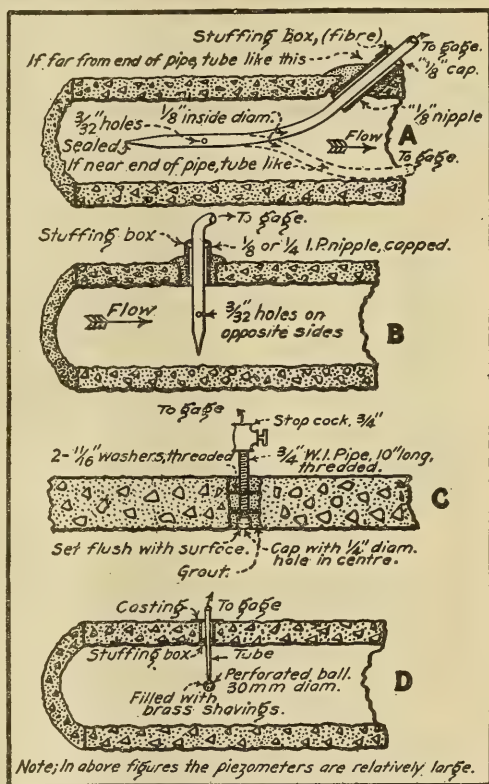


FIG. 3.—Various arrangements of piezometers for securing pressure head at a given place on the pipe line.

Current meter.—Where the water entered or left the pipe in an open channel the discharge was determined with a current meter, and the velocity in the pipe was secured by dividing this discharge by the area of the pipe. The two-tenths and eight-tenths depth method was used, as the results obtained in this way, when compared with the discharge found by the multiple-point method, generally agree with it to about 1 per cent.

TABLE 2.—*Velocities by color compared with velocities by weir and current meter.*

1	2	3	4	5	6	7	8	9	10
Pipe No. (this bul.).	Ref. No. (Bul. 376).	Pipe diameter.	Crest length of weir.	Meter method.	Velocity per second by color. (V_c).	Velocity per second by meter. (V_m).	Velocity per second by weir. (V_w).	$V_c - V_m$ V_c	$V_c - V_w$ V_c
		<i>Ins.</i>	<i>Feet.</i>		<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Per cent.</i>	<i>Per cent.</i>
	60	8	1.05 Cip. ¹		1.251		1.295		-3.8
	61	8	do.		1.736		1.735		.1
	62	8	2.84 Rect. ²		2.048		2.09		-2.0
	63	8	do.		3.043		2.97		2.4
	64	8	do.		3.294		3.37		-2.4
	132	18		6 tenths ³	2.08	1.99		4.3	
	192	48		2+8 ⁴	3.14	3.05		2.9	
	193	48		do.	3.75	3.71		1.1	
	194	48		do.	4.75	4.73		.4	
	263	78		Curve ⁵	.911	.928		-1.9	
	264	78		do.	.963	.974		-1.1	
	265	78		do.	1.51	1.60		-6.0	
	266	78		do.	2.063	2.08		-1.0	
	(6)	78		do.	2.16	2.10		2.8	
	269	78		do.	2.40	2.37		1.2	
	270	78		do.	2.44	2.42		.8	
	271	78		do.	2.79	2.51		3.1	
29	36		10.0 Cip. ¹	Int. ⁷	3.48	3.48	3.47	.0	.3
29	36		do.	6 tenths ³	3.48	3.55	3.47	-2.0	.3
30	42		8.02 Rect. ⁸		1.007		.980		2.7
30	42		do.		1.19		1.147		3.6
30	42		do.		1.41		1.351		4.2
30	42		do.		1.66		1.547		6.8
30	42		do.		1.75		1.734		.9
30	42		do.		1.96		1.947		.7
30	42		do.		2.24		2.130		4.9
30	42		do.		2.53		2.414		4.6
30	42		do.		2.91		2.769		4.8
(9)	36		4.99 Rect. ¹⁰		1.17		1.141		2.5
	36		do.		1.22		1.245		-2.0
	36		do.		1.89		1.830		3.2
	36		do.		2.69		2.619		2.6
	36		do.		2.75		2.612		5.0
	36		do.		2.90		2.805		3.3
	36		do.		2.99		2.935		1.8
	36		do.		3.74		3.713		.7
	36		do.		3.80		3.669		3.4

¹ Cipolletti weir with good conditions of contraction and velocity.

² Rectangular weir with end contractions and sharp crest.

³ Meter held in each vertical at 0.6 depth from surface.

⁴ Meter held at 0.2 and 0.8 depths in each vertical; mean accepted for vertical.

⁵ Rating curve developed by meter measurements. Velocity taken from curve.

⁶ Excluded from Table 2, Bul. 376, because gauge data lost for manometer No. 1.

⁷ Velocity integrated by moving meter slowly from top to bottom and return.

⁸ Indeterminate velocity of approach. Crest rounded.

⁹ Experiments on 36-inch lock-bar steel pipe.

¹⁰ Rectangular weir with suppressed contractions at both ends. Velocity of approach indeterminate.

Color.—Three chemicals were used in making powerful colors—fluorescein, Congo red, and potassium permanganate. About 1 teaspoonful of fluoreacein (in the form of red powder) mixed in about a pint of water gave sufficient solution for four injections of color in a pipe carrying up to 60 second-feet. The powder mixed readily in cold water. Congo red is used in the same way, but about 10 times as much "red" is necessary to obtain the same intensity of color.

In the use of potassium, a handful of the crystals made about 2 quarts of dense color. Cold water quickly attains a saturate solution if well stirred (from 5 to 8 per cent by weight at ordinary air temperature), and may then be poured off the undissolved crystals, which do not float. About 1 pint of solution will color 50 second-feet of clear water. Some waters break down the color to a muddy brown, which is unsatisfactory.

In making a test the coupling *W* (fig. 2) is opened and the solution poured into the reservoir *S*. After *W* is closed the gun is pumped up like a bicycle tire. Noting the time to a second, the operator opens the cock *V*.

The observer at the outlet notes to the second the first and last appearance of the color. The color is extended by the variation in the velocity throughout the section of the pipe. This extension covers from 8 to 12 per cent of the total time the color spends in the pipe. Comparison with carefully constructed weirs shows that the color method is correct within about 3 per cent. Wherever possible, a comparison between color and current meter was made. To secure comparative results, the time the color spent in the pipe is taken as from the moment of injection to the mean between first and last sight at the outlet. These comparative tests are shown in Table 2.

All watches used in the tests were compared before and after each experiment, corrections being noted for use in computing elapsed time. The watch agreeing best with jewelers' chronometers was used as the standard.

FIELD PROCEDURE.

After the reach of pipe was selected, the manometers attached, and other equipment put in readiness, the method for proceeding with the field test was in general carried out as described in the paragraphs following. Any necessary changes are noted in the text in connection with the description of the individual pipes tested.

The watches used at both ends of the reach were adjusted to agree to the second, and again compared at the end of the observation. Manometers were read at intervals varying from 30 seconds to 2 minutes (depending on the amount of pulsation in the water). If a weir was used to measure the discharge of water, a hook gauge above the weir was read every 2 to 5 minutes, depending on the variation of discharge. If a current-meter measurement was necessary to determine the discharge, it was made either during or immediately following the series of manometer readings, the manometers being watched for appreciable variations of discharge. Where color was used to time the actual velocity of the water it was injected into the pipe at approximately known intervals, say 5 minutes, throughout the time during which the manometers were read. Ordinarily the second gauge was near enough to the outlet of the pipe so that one observer could both read the manometer and watch for the appearance of the color. Sometimes an additional observer was necessary.

OFFICE EQUIPMENT AND METHODS.

Original multiplication, division, and addition were performed on mechanical devices, except in the computation of a few coefficients, where slide rules sufficed. Checking was done by 20-inch slide rules and graphic methods. Estimate diagrams were checked by proving random examples.

Office procedure.—Where water columns were used at both ends of the reach of pipe tested the loss of head in the pipe for the given velocity was the difference in elevation between the top of the mean water column at gauge No. 1 and the top of the mean column of gauge No. 2. Where a mercury manometer was used at one or both of the gauges the equivalent water column for each reading of the mercury column was computed. The mean of the elevations of the tops of the equivalent water columns was accepted as the elevation for that gauge. The loss of head was then computed as before. Standard methods were employed in computing current-meter data or weir discharge. Where color was used in timing the velocity of the water, the time was computed as from the instant of injection to the mean between first sight and last appearance of the color at the outlet.

ELEMENTS OF EXPERIMENTS FOR THE DETERMINATION OF FRICTION LOSSES IN CONCRETE PIPES, FLOWING FULL.

In the following pages two tables are arranged (Tables 3 and 4) which give the elements of all known observations on concrete pipes under pressure. The various series are arranged in ascending sizes of pipe and within one series the observations are arranged in ascending order of velocities.

EXPLANATORY NOTES ON TABLE 3.

Column 1 gives the consecutive numbers of the pipes followed in column 1, Table 4, also in the discussions in the following pages and in the Appendix. The small letter *a* after the numbers refers to discussion in the Appendix. Experiments conducted by this department are discussed in the text while the essential data secured from other sources are abstracted in the Appendix.

Column 2 shows the authority (see also column 2, Table 4) the series number where such was carried, together with the date of the test.

N refers to H. D. Newell, project manager, United States Reclamation Service, Umatilla project, Oregon.

F refers to J. T. Fanning.

B refers to the late Henry Bazin, France.

AB refers to Prof. A. Budau, Austria.

RDJ refers to R. D. Johnston, consulting engineer, Ontario Power Co., Canada.

M refers to F. F. Moore, designing engineer, board of water supply, New York City.

S refers to the writer, Fred. C. Scobey, senior irrigation engineer, in charge of experiments on the flow of water in channels and pipes. In these experiments and computations he was assisted by E. C. Fortier, P. A. Ewing, and Thomas H. McCarthy.

The other columns are considered self-explanatory.

EXPLANATORY NOTES ON TABLE 4.

Column 1 gives the same consecutive numbers as column 1, Table 3. See discussions after "Column 1" on page 20.

Column 10 gives the equation for the pipe, as developed by the tests. This equation is obtained by the "center of gravity" method—the equivalent of the "least squares" method in its simplest form.

The other columns are considered self-explanatory.

TABLE 3.—*Elements of experiments for the determination of friction losses in concrete pipes, running full; with retardation coefficients for various formulas.*

1	2	3	4	5	6	7	8	Coefficients of retardation.					
Pipe number.	Experimenter and year.	Observation.	Inside diameter.	Name and description of pipe.	Discharge per second.	Mean velocity, per second.	Loss of head, per 1,000 feet.	9	10	11	12	13	14
			<i>d</i>		<i>Q</i>	<i>V</i>	<i>H</i>	Scobey.	Chezy.	Williams-Hazen.	Moritz.	Kutten.	Weisbach.
								<i>C_s</i>	<i>C</i>	<i>C_w</i>	<i>C_m</i>	<i>n</i>	<i>f</i>
1	S 19 1915	1 2 3	<i>ins.</i> 8.0	Pomona, Calif.; jointed cement pipe on continuous down grade, straight; laid about 1885.	<i>cu. ft.</i> 1.22 1.24 1.24	<i>feet.</i> 3.51 3.56 3.56	<i>feet.</i> 10.800 10.780 10.820	0.291 .295 .295	82.6 83.8 83.8	94.8 96.3 96.1	0.95 .98 .98	0.0124 .0123 .0123	.0378 .0357 .0359
2	S 21 1915	2 1 3 4	10.0	Pomona, Calif.; jointed cement pipe on continuous down grade, straight; laid 1888.	1.10 1.12 1.13 1.14	2.02 2.06 2.08 2.10	3.120 3.129 3.334 3.403	.271 .276 .270 .270	79.2 80.8 79.1 79.0	92.9 94.6 92.3 92.3	.96 .98 .95 .95	.0134 .0132 .0134 .0134	.0410 .0396 .0414 .0414
3	S 28 1915	1 2	10.0	Ontario, Calif.: jointed cement pipe, on continuous grade.	2.59 2.65	4.75 4.87	15.900 15.850	.283 .290	82.6 84.8	90.7 93.1	.91 .94	.0130 .0126	.0378 .0358
4	S 20 1915	1 2	12.0	Pomona, Calif.; jointed cement pipe, on continuous grade.	1.25 1.25	1.60 1.61	1.793 1.884	.253 .248	76.2 73.2	88.4 86.6	.91 .89	.0144 .0147	.0451 .0468
5	S 26 1915	10 9 1 2 3 4 5 6 8 7	12.0	Pomona, Calif.; jointed cement pipe, straight and approximately level, clear water; laid 1885.	1.18 1.32 1.54 1.57 1.70 1.80 2.10 2.24 2.71 2.85	1.50 1.68 1.95 2.00 2.17 2.29 2.68 2.85 3.45 3.63	1.624 2.120 2.188 2.497 2.925 3.342 4.423 4.918 7.055 7.649	.244 .244 .280 .268 .268 .265 .270 .272 .275 .278	72.8 73.0 83.8 80.0 80.4 79.2 80.7 81.4 82.1 82.9	85.4 84.8 97.3 92.4 92.0 90.4 90.9 91.3 91.0 91.6	.88 .87 1.00 .94 .94 .92 .92 .92 .92 .92	.0148 .0148 .0133 .0138 .0137 .0139 .0137 .0136 .0133 .0135	.0485 .0484 .0367 .0402 .0401 .0411 .0396 .0390 .0382 .0374
6	S 33 1915	1	12.0	Ontario, Calif.; jointed cement pipe, straight; laid 1911.	4.59	5.85	14.820	.322	95.9	103.3	1.03	.0120	.0279
7	S 27 1915	2 1	12.0	Ontario, Calif.; jointed cement pipe, straight and level; laid 1900.	1.51 1.57	1.92 2.00	1.405 1.489	.343 .347	102.1 103.6	121.1 122.2	1.25 1.26	.0114 .0112	.0246 .0240
8	S 53 1916	1 6	11.8	Oakdale, Calif.; jointed cement pipe, slight sag in profile.	.98 1.18	1.29 1.55	1.310 1.769	.240 .249	71.8 74.4	85.2 87.3	.88 .90	.0148 .0145	.050 .0465

TABLE 3.—*Elements of experiments for the determination of friction losses in concrete pipes, running full; with retardation coefficients for various formulas—Continued.*

1	2	3	4	5	6	7	8	Coefficients of retardation.					
								9	10	11	12	13	14
Pipe number.	Experimenter and year.	Observation.	Inside diameter. <i>d</i>	Name and description of pipe.	Discharge per second. <i>Q</i>	Mean velocity, per second. <i>V</i>	Loss of head, per 1,000 feet. <i>H</i>	Scobey. <i>C_s</i>	Chey. <i>C</i>	Williams-Hazen. <i>C_W</i>	Moritz. <i>C_m</i>	Kutten. <i>n</i>	Weisbach. <i>f</i>
			<i>ins.</i>		<i>cu. ft.</i>	<i>feet.</i>	<i>feet.</i>						
9	S 24 1915	1	16.0	Pomona, Calif.; jointed cement pipe, straight, on continuous down grade; pipe clean; laid 1883.	1.37	.98	.536	.237	73.1	86.8	.90	.0154	.0478
		2			1.54	1.10	.512	.272	84.6	99.8	1.03	.0132	.0362
		3			1.62	1.16	.570	.272	84.1	99.4	1.02	.0128	.0363
10	S 22 1915	4	16.0	Pomona, Calif.; jointed cement pipe, straight, on continuous down grade; pipe clean; laid 1883.	2.40	1.72	1.001	.304	94.5	108.6	1.11	.0127	.0290
		5			2.47	1.77	1.051	.305	94.6	108.9	1.11	.0127	.0287
		3			2.61	1.87	1.251	.296	91.7	104.7	1.07	.0130	.0306
		2			2.74	1.96	1.315	.302	93.8	106.9	1.09	.0128	.0293
		7			2.82	2.02	1.415	.300	93.1	105.9	1.08	.0129	.0297
		1			2.92	2.09	1.445	.307	95.4	108.2	1.10	.0127	.0283
		6			3.35	2.40	1.964	.303	93.8	105.4	1.07	.0129	.0292
		8			3.41	2.44	2.088	.292	92.4	103.6	1.05	.0129	.0305
11	S 25 1915	1	16.0	Pomona, Calif.; jointed cement pipe, continuous grade.	2.40	1.72	.984	.306	95.0	109.7	1.12	.0127	.0285
12a	N 1 1912	....	16.0	Z _a siphon, Umatilla project, U. S. Reclamation Service, Oreg.	3.74	2.68	3.800	.243	75.0	82.4	.82	.0154	.0453
					4.87	3.49	4.500	.291	90.0	98.0	.98	.0134	.0317
13a	N 2 1912	....	16.0	Z _b siphon, Umatilla project.	3.42	2.45	1.900	.314	98.0	109.5	1.11	.0125	.0271
14	S 58 1916	1	18.0	Edwards line, Oakdale irrigation district, Calif.; straight siphon.	3.48	1.97	1.625	.254	79.8	88.9	.89	.0148	.0405
		2			3.79	2.15	1.930	.254	79.8	88.3	.88	.0150	.0405
15	S 56 1916	1	18.0	Batdorf line, Oakdale irrigation district; straight down grade.	1.70	.96	.309	.284	89.7	106.6	1.11	.0132	.0321
16	S 42 1916	6	19.7	Clateral, Kamloops, B. C., Canada; straight in alignment, wavy in profile, rough joints; laid 1911.	.79	.37	.056	.246	78.1	98.3	1.03	.0133	.0429
		2			1.07	.50	.109	.238	75.8	92.7	.96	.0145	.0459
		3			1.75	.84	.272	.249	79.2	93.6	.95	.0148	.0417
		4			2.35	1.12	.466	.255	81.3	93.7	.95	.0147	.0397
		5			2.63	1.25	.538	.264	84.4	96.8	.98	.0143	.0371
		7			2.93	1.39	.745	.251	79.6	90.6	.91	.0151	.0412
		1			3.12	1.48	.781	.260	82.7	93.9	.94	.0144	.0382
17	S 46 1916	4	19.7	Bishop lateral, Kamloops, B. C., Canada; jointed cement pipe, gentle curve in alignment, on continuous down grade; laid 1911.	1.33	.63	.102	.307	98.6	120.0	1.24	.0124	.0271
		5			1.98	.94	.215	.315	100.0	119.5	1.22	.0121	.0257
		7			3.14	1.49	.557	.310	98.7	113.4	1.14	.0126	.0265
		8			3.70	1.76	.744	.316	100.4	114.2	1.15	.0126	.0255
		6			4.13	1.96	.946	.313	99.5	112.0	1.12	.0127	.0260
18	S 60 1916	5	19.9	Temescal Water Co., Corona, Calif.; inverted siphon of jointed cement pipe reinforced, straight in alignment, double reverse curve in profile; laid 1911.	2.14	.99	.200	.340	108.4	129.4	1.33	.0119	.0220
		4			3.63	1.68	.580	.339	108.1	123.7	1.25	.0118	.0221
		2			4.07	1.88	.700	.346	109.8	125.3	1.26	.0117	.0212
		3			5.13	2.37	1.094	.349	111.3	124.3	1.24	.0116	.0208
		1			5.50	2.54	1.278	.346	110.4	122.5	1.22	.0117	.0212
19	F 1880	1	20.0	Wrought-iron cement-lined pipe, 8,171 feet long according to Schmeer.	2.07	.95	.230	.304	97.4	115.2	1.18	.0124	.0274
		2			3.25	1.49	.440	.345	109.8	127.2	1.29	.0115	.0213
		3			4.20	1.92	.730	.349	110.7	125.1	1.26	.0116	.0212
		4			5.08	2.33	1.040	.351	112.0	125.1	1.25	.0116	.0206
		5			5.67	2.60	1.340	.345	110.1	121.7	1.21	.0117	.0213
		6			6.26	2.87	1.580	.351	111.7	122.8	1.22	.0115	.0205
		7			7.14	3.27	1.990	.356	113.5	123.7	1.23	.0114	.0200
		8			7.50	3.44	2.280	.350	111.7	120.9	1.20	.0116	.0207
		9			8.16	3.74	2.720	.349	111.1	119.6	1.18	.0117	.0209
		10			8.55	3.92	3.000	.348	110.8	118.9	1.17	.0118	.0210
		11			8.73	4.00	3.130	.348	110.7	118.5	1.17	.0118	.0210
		12			8.82	4.04	3.200	.347	110.6	118.3	1.16	.0118	.0210
20	S 57 1916	1	23.7	Clavey siphon, Oakdale irrigation district, Calif.; monolithic, on gentle up-grade; built 1912.	4.77	1.55	.426	.328	106.7	120.9	1.21	.0122	.0226
		2			5.59	1.82	.543	.340	110.7	124.4	1.24	.0119	.0210
		3			6.02	1.95	.522	.373	121.6	136.7	1.36	.0110	.0174

TABLE 3.—Elements of experiments for the determination of friction losses in concrete pipes, running full; with retardation coefficients for various formulas—Continued.

1	2	3	4	5	6	7	8	Coefficients of retardation.					
Pipe number.	Experimenter and year.	Observation.	Inside diameter.	Name and description of pipe.	Discharge per second.	Mean velocity, per second.	Loss of head, per 1,000 feet.	9	10	11	12	13	14
			<i>d</i>		<i>Q</i>	<i>V</i>	<i>H</i>	Scobey.	Chezy.	Williams-Hazen.	Moritz.	Kutten.	Welsbach.
					<i>cu. ft.</i>	<i>feet.</i>	<i>feet.</i>	<i>C_s</i>	<i>C</i>	<i>C_w</i>	<i>C_m</i>	<i>n</i>	<i>f</i>
21	S 47 1916	4 2 3 1	ins. 23.5	"A" lateral, Kamloops, B. C., Canada; nominally a 24-inch jointed cement pipe, but obstructed by débris.	1.73 2.32 2.65 3.63	.63 .84 .97 1.32	.103 .230 .296 .495	.268 .241 .243 .257	88.4 78.8 79.2 84.0	104.9 91.2 91.2 94.3	.94 .81 .81 .82	.0134 .0154 .0155 .0150	.0338 .0416 .0408 .0367
22	S 61 1916	1 8 7 6 5 4 3 2	30.0	Temescal Water Co., Corona, Calif.; inverted siphon, jointed concrete pipe, straight in alignment, sag in profile; laid 1911.	3.25 6.38 8.23 8.28 8.38 8.38 8.52 9.11	.67 1.31 1.69 1.70 1.72 1.72 1.75 1.87	.094 .384 .635 .644 .253 .634 .700 .806	.261 .253 .254 .253 .253 .258 .250 .249	87.3 84.5 84.9 85.0 84.3 86.4 83.7 83.5	102.1 93.6 92.0 91.8 91.5 93.7 90.4 89.5	1.03 .92 .90 .90 .90 .92 .88 .87	.0142 .0156 .0156 .0156 .0157 .0154 .0158 .0159	.0339 .0359 .0357 .0357 .0360 .0344 .0367 .0370
23	S 34 1915	3 2 1	30.0	D ₁ siphon, Umatilla project, U. S. Reclamation Service, Oreg.; jointed concrete pipe.	5.10 8.74 12.00	1.04 1.78 2.45	.150 .405 .745	.320 .334 .339	108.3 112.0 113.0	123.1 123.3 122.1	1.23 1.22 1.19	.0123 .0125 .0125	.0224 .0206 .0200
24a	N 3 1911	2 2 1	30.0	D ₁ siphon, same as No. 23 above; tests made when pipe was new and clean.	16.62 17.04 17.70	3.39 3.47 3.61	1.050 1.050 1.070	.395 .404 .416	132.0 135.0 140.0	140.4 143.7 148.0	1.37 1.40 1.44	.0108 .0106 .0103	.0147 .0140 .0132
25a	N 4 1912	1	30.0	R ₃ siphon, Umatilla project, U. S. Reclamation Service, Oreg.	13.40	2.73	.860	.351	118.0	126.0	1.23	.0119	.0186
26	S 51 1916	6 5 1 4 7 3 2	30.5	Prosser pressure pipe, Sunnyside project, U. S. Reclamation Service, Wash., jointed concrete pipe reinforced, on continuous down grade, straight and clean; laid 1911.	24.80 25.60 26.20 26.60 26.60 28.80 28.90 29.40	4.88 5.04 5.15 5.24 5.24 5.67 5.68 5.78	2.230 2.653 2.644 2.869 2.869 3.805 3.757 3.727	.386 .366 .375 .365 .365 .343 .346 .354	129.4 122.6 125.6 122.4 124.8 115.2 116.9 118.7	133.0 125.1 128.0 124.8 115.9 116.9 119.5	1.28 1.20 1.23 1.19 1.10 1.10 1.14	.0111 .0146 .0114 .0116 .0123 .0121 .0119	.0154 .0171 .0163 .0171 .0194 .0191 .0183
27a	B 1895	1 2 3 4 5 6 7 8 9	31.5	Short experimental conduit at Dijon, France, joints perfect, exceeding smoothness indicated by retardation factors.	16.27 18.70 19.78 22.71 25.22 25.93 26.66 31.49 35.66	3.01 3.46 3.65 4.20 4.72 4.79 4.92 5.82 6.59	.673 .925 1.050 1.375 1.725 1.750 1.850 2.575 3.275	.424 .416 .413 .418 .416 .419 .419 .420 .421	142.4 140.4 139.5 139.4 140.5 141.7 141.5 141.5 142.3	153.2 148.6 146.9 145.7 145.1 146.1 145.7 144.0 143.2	1.49 1.44 1.42 1.41 1.38 1.41 1.40 1.38 1.36	.0104 .0106 .0106 .0107 .0106 .0106 .0106 .0106 .0106	.0126 .0131 .0133 .0132 .0131 .0129 .0129 .0129 .0128
28	S 55 1916	4	36.0	Clavey siphon, Oakdale irg. dist., Calif., monolithic pipe, built with wood forms, continuous down grade; built 1912.	12.70 13.40 13.50 13.70 13.80	1.80 1.89 1.91 1.94 1.95	.438 .430 .464 .270 .587	.290 .351 .298 .270 .271	99.3 120.3 102.2 92.8 92.8	106.5 130.6 109.4 98.4 98.5	1.04 1.28 1.06 .95 .95	.0140 .0119 .0137 .0150 .0150	.0260 .0178 .0246 .0300 .0299
28b	S 54 1916	1 2 3											
29	S 36 1916	1	36.0	Deer Flat Forest pipe line, Boise project, U. S. Reclamation Service, Idaho.	24.60	3.48	1.170	.343	117.6	121.2	1.16	.0123	.0187
29b	S 36b 1917	1 2 4 6 5 3		Same reach of same pipe two years later; laid 1912; straight in horizontal alignment.	38.60 50.00 52.60 58.10 61.30 64.10	5.45 7.12 7.44 8.22 8.66 9.06	2.072 3.612 3.509 5.328 5.321 5.30	.403 .399 .423 .379 .400 .419	138.3 136.5 145.2 130.1 137.2 143.8	139.4 134.8 141.3 126.2 133.2 139.6	1.33 1.26 1.35 1.18 1.25 1.31	.0110 .0110 .0105 .0115 .0108 .0105	.0134 .0137 .0123 .0152 .0136 .0124
30	S 49 1916	5 6 7 8 9 2 3 4	42.0	Victoria aqueduct, B. C., Canada; siphon No. 1, jointed concrete pipe, reinforced; much curvature, extremely smooth interior, joints included; conditions unusually favorable for experimentation; laid 1914.	9.68 11.45 13.56 15.97 16.84 18.86 21.55 24.34 27.99	1.01 1.19 1.41 1.66 1.75 1.96 2.24 2.53 2.91	.076 .097 .136 .179 .212 .253 .316 .415 .530	.354 .370 .370 .380 .368 .377 .385 .380 .387	123.9 129.2 129.2 132.7 128.5 131.7 134.9 132.8 135.1	139.6 214.4 214.2 714.4 139.1 714.1 9143.5 139.9 1141.0	1.33 1.37 1.34 1.31 1.34 1.36 1.32 1.28 1.26	.0112 .0113 .0111 .0110 .0114 .0112 .0110 .0112 .0111	.0168 .0155 .0154 .0146 .0156 .0148 .0142 .0141 .0141

TABLE 3.—*Elements of experiments for the determination of friction losses in concrete pipes, running full; with retardation coefficients for various formulas—Continued.*

1	2	3	4	5	6	7	8	Coefficients of retardation.					
Pipe number.	Experimenter and year.	Observation.	Inside diameter.	Name and description of pipe.	Discharge per second.	Mean velocity, per second.	Loss of head, per 1,000 feet.	9	10	11	12	13	14
			<i>d</i>		<i>Q</i>	<i>V</i>	<i>H</i>	<i>C_s</i>	<i>C</i>	<i>C_{uv}</i>	<i>C_m</i>	<i>n</i>	<i>f</i>
			<i>ins.</i>		<i>cu. ft.</i>	<i>feet.</i>	<i>feet.</i>						
31	S 48 1916	1	42.0	Victoria aqueduct, siphon No. 5 (see No. 30 above); series not so trustworthy as No. 30; reach much shorter; ignore observation 1.	9.50	.99	.042	.466	163.0	188.2	1.88	.0084	.0097
		5			18.50	1.92	.214	.402	140.4	151.8	1.48	.0105	.0131
		4			20.90	2.17	.275	.400	139.9	149.7	1.45	.0106	.0132
		3			21.60	2.24	.310	.389	136.2	145.1	1.40	.0109	.0139
		2			24.90	2.59	.429	.382	133.7	140.6	1.35	.0112	.0145
32	S 35 1913	3	46.0	R ₁ siphon, Umatilla project, U. S. Reclamation Service, Oreg.; jointed concrete.	16.20	1.41	.096	.416	147.0	162.4	1.59	.0099	.0119
		2			25.10	2.18	.252	.397	139.7	149.0	1.44	.0108	.0131
		1			36.50	3.17	.544	.393	139.0	143.1	1.36	.0109	.0134
33a	N 5 1911 1912	2	46.0	R ₁ siphon, same as No. 32 above; tests made when pipe was new.	45.90	3.98	.780	.412	145.0	147.9	1.40	.0106	.0122
		1			46.20	4.00	.870	.392	138.0	140.2	1.33	.0111	.0134
		3			48.20	4.17	1.080	.375	130.0	129.9	1.23	.0117	.0153
		4			48.60	4.21	1.020	.381	135.0	135.3	1.28	.0113	.0142
33b	S 60	1	48.0	Churn Creek siphon, Anderson-Cottonwood irg. dist., Calif.	47.40	3.77	1.145	.313	111.0	111.0	1.04	.0137	.0208
34	S 52 1916	1	54.0	Mabton pressure pipe, Sunnyside project, Wash.	80.80	4.99	1.249	.368	132.7	129.4	1.20	.0118	.0146
35	S 40 1915	6	63.5	Simms Creek siphon, Sun River project, U. S. Reclamation Service, Mont.; monolithic pipe, straight in alignment; built 1907-8	66.40	3.02	.289	.420	154.1	156.7	1.47	.0104	.0108
		5			78.00	3.55	.377	.432	159.2	159.6	1.49	.0101	.0102
		1			86.60	3.94	.459	.434	160.2	159.2	1.49	.0101	.0101
		4			123.30	5.61	1.194	.384	141.0	135.3	1.24	.0114	.0129
		3			130.60	5.94	1.286	.391	143.8	137.7	1.26	.0112	.0124
36a	AB 1913	1	86.6	Perlmoos cement works, Austria; gentle curves in alignment, on continuous down grade; original data do not describe pipe manufacture or surface.	140.40	6.39	1.581	.380	133.7	132.4	1.21	.0116	.0132
		2			58.40	1.43	.066	.344	130.9	136.1	1.28	.0123	.0148
		1			90.50	2.21	.155	.345	132.4	131.9	1.23	.0124	.0147
		3			113.90	2.78	.181	.402	153.7	152.6	1.42	.0108	.0109
		4			131.90	3.22	.312	.355	136.0	131.8	1.21	.0122	.0140
		5			152.10	3.68	.402	.358	137.0	131.4	1.21	.0122	.0138
37a	M 1	6		166.70	4.08	.496	.356	136.3	129.7	1.18	.0122	.0139	
			110.0	Catskill aqueduct siphons..	542.00	8.21	1.150	.405	160.0	142.7	1.26	.0109	.0101
38	S 59 1916	4	120.0	Whitney siphon, Los Angeles aqueduct, Calif., monolithic pipe, cement mortar coat.	223.00	2.84	.191	.326	130.4	123.4	1.12	.0133	.0152
		3			236.00	3.01	.211	.328	131.2	123.6	1.12	.0132	.0151
		2			238.00	3.03	.284	.285	113.5	106.1	.96	.0153	.0199
39a	M 2 1915	5	174.0	Rondout tunnel, Catskill aqueduct, N. Y.; monolithic tunnel lining made with oiled steel forms, observations made on consecutive days.	260.90	1.58	.031	.357	150.0	144.8	1.31	.0124	.0116
		4			345.00	2.09	.051	.368	155.0	146.4	1.32	.0119	.0109
		6			469.00	2.84	.112	.338	140.5	130.1	1.18	.0131	.0130
		3			472.30	2.86	.089	.381	159.0	148.4	1.32	.0116	.0102
		2			620.90	3.76	.155	.380	159.0	144.5	1.28	.0116	.0102
		7			624.20	3.78	.211	.327	137.0	123.0	1.08	.0134	.0138
		8			756.30	4.58	.319	.323	135.0	119.2	1.04	.0136	.0142
		1			771.20	4.67	.253	.369	154.0	137.8	1.21	.0119	.0108
40a	M 3 1915	6	174.0	Walkill tunnel, Catskill aqueduct, N. Y., monolithic tunnel lining made with oiled steel forms; observations made on same day that identical discharge held in pipe No. 39 above, which see.	260.90	1.58	.033	.346	143.5	140.1	1.27	.0129	.0123
		5			345.00	2.09	.051	.368	154.0	146.4	1.35	.0120	.0109
		7			469.00	2.84	.107	.345	144.0	133.4	1.19	.0128	.0124
		4			472.30	2.86	.092	.374	157.0	145.7	1.30	.0118	.0105
		3			620.90	3.76	.192	.341	143.0	128.7	1.14	.0129	.0127
		8			624.20	3.78	.170	.365	152.0	138.2	1.22	.0121	.0111
		1			736.50	4.46	.249	.356	149.0	132.7	1.17	.0124	.0117
		9			756.30	4.58	.261	.357	149.0	132.9	1.17	.0123	.0116
		2			771.20	4.67	.269	.358	149.5	133.2	1.17	.0123	.0115
41a	RDJ 1913 1914		216.0	Conduit No. 2, Ontario Power Co., Canada. See p. 84 for explanation of items in this table. They do not represent data on actual individual runs, but are from velocity-friction curve.	1,018.00	4.00	.108	.424	181.0	163.0	1.436	.0104	.0098
					2,086.00	8.00	.448	.416	178.0	152.0	1.304	.0105	.0102
					3,045.00	12.00	.990	.420	180.0	148.0	1.256	.0104	.0100
					4,063.00	16.00	1.701	.427	183.0	148.0	1.242	.0102	.0097
					5,091.00	20.00	2.397	.450	193.0	153.0	1.286	.0097	.0087

TABLE 4.—Summary of series of experiments upon concrete pipes running full, including individual pipe equations. To be considered as supplementary to table 3.

1	2	3	4	5	6	7	8	9	10
Pipe No.	Experimenter.	Age of pipe.	Maximum pressure head.	Diameter of bore.	Diameter of bore.	Length of reach tested.	Area of bore.	Range of velocities.	Individual pipe equations.
		<i>Years.</i>	<i>Feet.</i>	<i>Inches.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Sq. ft.</i>	<i>Ft. per sec.</i>	
1	Scobey	30	7	8.0	0.67	1,310.9	0.349	3.51-3.56	
2	do	27	5	10.0	.83	1,107.0	.545	2.02-2.10	
3	do	10	5	10.0	.83	936.2	.545	4.75-4.87	
4	do	30	4	12.0	1.00	621.1	.785	1.60-1.61	
5	do	30	4	12.0	1.00	182.8	.785	1.50-3.63	$H=0.7406 V^{1.813}$
6	do	4	8	12.0	1.00	217.8	.785	5.85	
7	do	15	5	12.0	1.00	869.4	.785	1.92-2.00	
8	do		8	11.8	.98	1,850.8	.762	1.29-1.55	
9	do	32	4	16.0	1.33	785.0	1.396	0.98-1.16	
10	do	32	2	16.0	1.33	853.8	1.396	1.72-2.44	$H=0.3464 V^{1.985}$
11	do	32	2	16.0	1.33	1,897.6	1.396	1.72	
12a	Newell	2	18	16.0	1.33		1.396	2.68-3.49	
13a	do	2	18	16.0	1.33		1.396	2.45	
14	Scobey		11	18.0	1.50	1,271.5	1.767	1.97-2.15	
15	do		3	18.0	1.49	559.3	1.703	.96	
16	do	3	10	19.7	1.64	1,116.0	2.106	.37-1.48	$H=0.3727 V^{1.883}$
17	do	4	6	19.7	1.64	771.8	2.106	.63-1.96	$H=0.2484 V^{1.981}$
18	do	4	80	20.0	1.66	2,163.2	2.166	.99-2.54	$H=0.2116 V^{1.501}$
19	Fanning			20.0	1.67			.95-4.04	$H=0.2186 V^{1.503}$
20	Scobey	3	40	23.8	1.98	1,046.2	3.079	1.55-1.95	
21	do	5	7	24.0	2.00	2,306.5	3.142	.63-1.32	$H=0.2978 V^{2.078}$
22	do	4	8	29.9	2.49	880.0	4.870	.67-1.87	$H=0.2272 V^{2.054}$
23	do	5	45	30.0	2.50	5,026.4	4.909	1.04-2.45	$H=0.1394 V^{1.862}$
24a	Newell	1	45	30.0	2.50			3.39-3.61	
25a	do	4	25	30.0	2.50			2.73	
26	Scobey	4	50	30.5	2.54	2,276.3	5.075	4.88-5.78	$H=0.01478 V^{3.189}$
27a	Bazin	New.		31.5	2.62	131.0	5.413	3.00-6.59	$H=0.0811 V^{1.971}$
28	Scobey	3	30	36.0	3.00	1,933.6	7.070	1.80-1.89	
28b	do	3	30	36.0	3.00	1,266.0	7.070	1.91-1.95	
29	do	3	70	36.0	3.00	7,282.0	7.070	3.48	
29b	do	5	70	36.0	3.00	7,285.0	7.070	5.45-9.06	$H=0.0497 V^{2.166}$
30	do	1	65	42.0	3.50	1,336.1	9.620	1.01-2.91	$H=0.0711 V^{1.889}$
31	do	1		42.0	3.50	378.0	9.620	.99-2.59	$H=0.0432 V^{2.423}$
32	do	5	110	46.0	3.82	9,774.0	11.520	1.41-3.17	$H=0.0456 V^{2.166}$
33a	Newell	1-2	110	46.0	3.83	9,831.0		3.98-4.21	
33b	Scobey	4	25	48.0	4.00	4,242.3	12.570	3.77	
34	do	7	60	54.0	4.54	2,167.4	16.188	4.99	
35	do	7	40	63.5	5.29	1,138.0	21.979	3.02-6.39	$H=0.0787 V^{2.400}$
36a	Budau	New.	38	86.6	7.22	4,200.0	40.919	1.43-4.08	$H=0.03345 V^{1.912}$
37a	Moore		Var.	110.0					
38	Scobey	3	65	120.0	10.00	857.4	78.540	2.84-3.03	
39a	Moore	New.	710	174.0	14.50	8,419.0	165.130	1.58-4.67	$H=0.01113 V^{2.109}$
40a	do	New.	710	174.0	14.50	13,941.0	165.130	1.58-4.67	$H=0.01203 V^{2.029}$
41a	Johnston	4			18.00	6,466.0	254.560	4.00-20.00	$H=0.0082 V^{1.93}$

DESCRIPTION OF PIPES.

The descriptions in the following pages are to be taken as supplementing Tables 3 and 4. The methods of determining the hydraulic elements necessary for each observation are described. The descriptions of pipes upon which previous experimenters have made observations are given in the appendix.

No. 1, Experiment S-19.—8-inch jointed cement pipe, Irrigation Co. of Pomona, Calif.—This length of pipe line, between boxes 86 and 89 on Reservoir Street, near Pomona, is straight in both vertical and horizontal alignment. From an examination of its inlet it is probably safe to say that joints in this, as in so many other of the older pipes, were not as carefully made as they are at present.

Water columns were used for both gauges, No. 1 being attached to a brass piezometer tube of type A, thrust 5.8 feet down the 8-inch pipe from the 24-inch riser pipe similar to the one in Plate III, figure

2. Water entered the riser from an 8-inch pipe directly opposite the pipe line tested. In the reach, 1,310.9 feet long between gauges there are 3 smaller riser pipes. Gauge No. 2 is attached to a piezometer identical in construction with No. 1, held in a position 3 feet above the outlet of the pipe.

The water for this system is clear, being pumped from wells in the "Palomares Cienaga."¹ So far as the writer was able to determine from the inlets and outlets of pipes in this system, there was no deposit of either vegetable or mineral nature.

The nominal diameter of the pipe was used in computing the area and quantity. As the velocity was found by the direct method, any difference between the true and the nominal area does not affect the velocity. If methods of construction used in the eighties were the same as to-day, it is possible the pipe is undersized, as that appears true of most present-day pipes.

As it was not practicable materially to vary the discharge in the pipe the three observations were taken at about the same velocity, although extended over two days. The velocity for any one run was taken as the mean of three batches of fluorescein, injected with a "color gun" into the intake of the pipe line at the foot of the riser pipe at gauge 1, and observed in the low riser pipe at gauge 2. Water was immediately withdrawn from the pool so that there was no uncertainty due to color lagging at the outlet.

The capacity of this pipe is slightly greater than that of most pipes built in the eighties, but it appears to be absolutely clean, though with rough joints. The value of C_s is about 0.292.

No. 2, Experiment S-21.—10-inch jointed cement pipe, Irrigation Co. of Pomona, Calif.—This pipe line, between boxes 364 and 366, was laid in 1888. The gauges and piezometer connections were identical with those used and described under No. 1. Piezometer No. 1 was placed 6 feet down the pipe line from the riser pipe forming delivery box No. 364 while piezometer No. 2 was thrust 1.7 feet into the pipe against the current, from box No. 366. A reach of line 1,107 feet long, straight in alignment and profile, was thus tested. Three batches of fluorescein were timed for each observation, the mean time being accepted in computing velocity of the water. The nominal diameter was accepted in computing areas and quantity of water (see No. 1, p. 25). So far as is known, this line had never been disturbed since it was laid. There is probably little or no sediment in the line, as the water is clear. The capacity of this line is slightly more than usual in this vicinity, the value of C_s being about 0.272.

No. 3, Experiment S-28.—10-inch jointed cement pipe, San Antonio Water Co., Ontario, Calif.—This experiment was conducted on a straight reach of pipe laid in 1905 diagonally through an orange grove. In the 10 years since then it has not been necessary to dig up the pipe for root troubles. The nominal diameter was accepted in computing area and quantity of water (see No. 1, p. 25). Both gauges consisted of piezometer tubes of type A leading to water columns in glass. The orifices for gauge 1 were located 12.8 feet down the pipe from its intake in a masonry division box, while those for gauge 2 were 936.2 feet farther downstream, and 2 feet above the

¹ The Use of Underground Water for Irrigation at Pomona, Calif., by C. E. Tait, O. E. S. Bul. 236, U. S. D. A., p. 35.

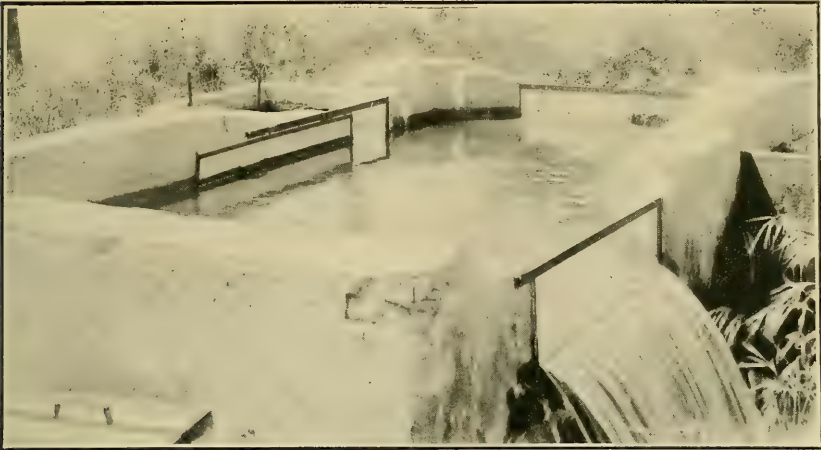


FIG. 1.—DIVISION BOX OVER PIPE LINE SYSTEM IN CALIFORNIA.

Where color is used to determine velocity in pipe entering such a box, the last trace of color can not be determined directly, as whole pool is then tinted. See page 14.



FIG. 2.—DIVISION STAND ON PIPE SYSTEM IN CALIFORNIA.

Piezometer tube is thrust into pipe line and pressure head siphoned over edge of stand to glass gauge tube. Note small iron pipes, in order to allow escape of air near inlet to pipes conveying water from the stand. See page 53.



FIG. 3.—SIMMS CREEK SIPHON, SUN RIVER PROJECT, U. S. RECLAMATION SERVICE, MONTANA. (PIPE No. 35.)

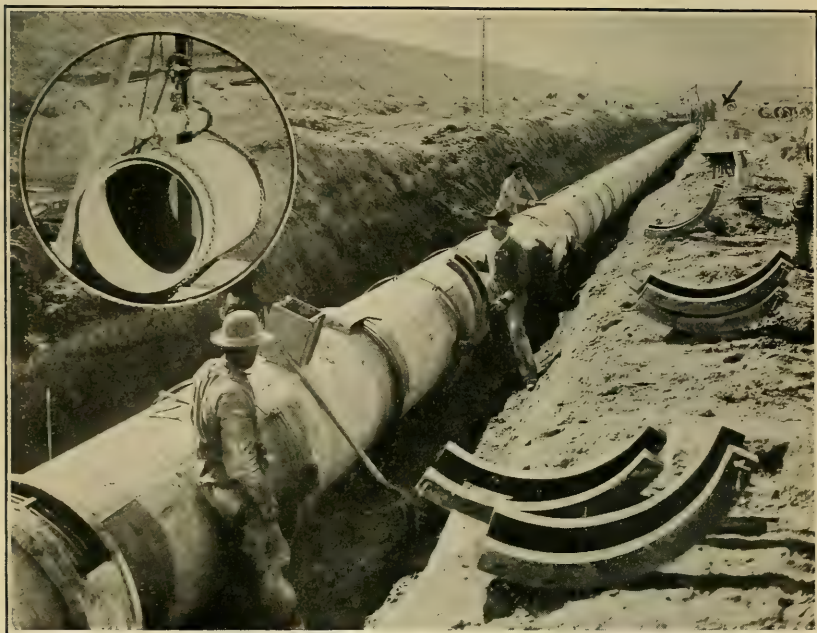


FIG. 1.—DEER FLAT FOREST PIPE LINE, BOISE PROJECT, U. S. RECLAMATION SERVICE, IDAHO. (PIPE No. 29.)

Note reinforcement and forms for collar joints. Intake at end of trench in distance. Inset shows pipe unit over trench.

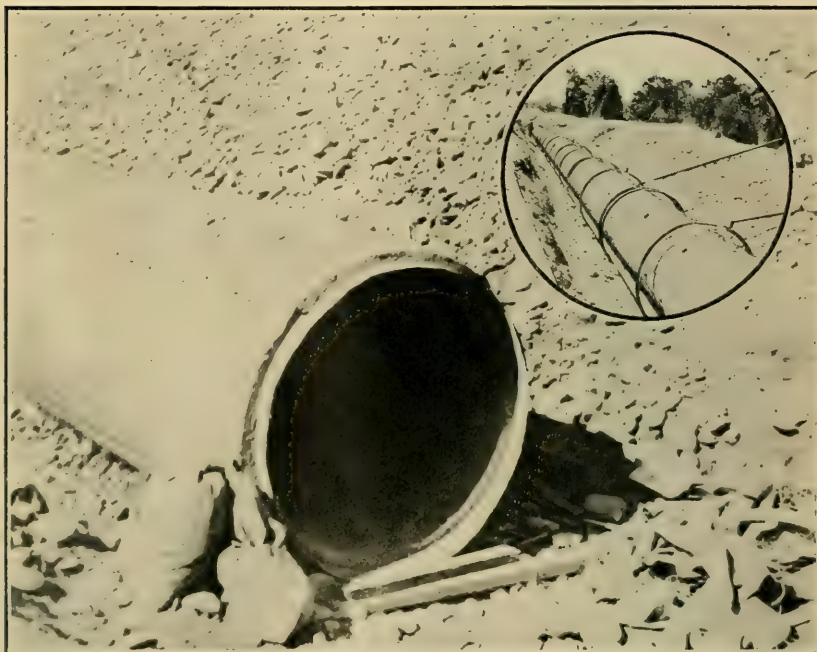


FIG. 2.—CHURN CREEK SIPHON, ANDERSON-COTTONWOOD IRRIGATION DISTRICT, CALIFORNIA. (PIPE No. 33b.)

Longitudinal ridges on interior surface similar to those shown on exterior; due to cracks between form boards. Inset shows inside forms set for monolithic pouring.

outlet of the pipe to another division box. The mean velocity of four batches of color was taken as the velocity of the water for each of the two runs of water. Unfortunately it was not practicable to vary to a marked degree the quantity flowing in the pipe. The high velocities in this pipe and the clear water probably assure a pipe free from sediment. This is borne out by the value of $C_s = 0.287$, the increase in this coefficient marking the improvement in the joints.

No. 4, Experiment S-20.—12-inch jointed cement pipe, Irrigation Co. of Pomona, Calif.—After passing through the reach of pipe described as No. 1, water may be delivered to the consumer or enter this reach of 12-inch pipe between boxes 89 and 90, on Franklin Street, Pomona.

Water columns were used for both gauges, which were attached to peizometer tubes of type A, No. 1 being placed 10 feet down the line from the inlet and No. 2 being thrust 2 feet up from the outlet. Velocities were computed from the mean time of three batches of fluorescein, poured into the inlet and noted at the outlet. The color dragged out from 10 to 14 per cent of the total time spent in the pipe, indicating a very rough interior.

Little is known of the condition of this pipe, as it was laid about 1885. The nominal diameter was accepted in computing area and quantity of water (see No. 1, p. 25). So far as could be ascertained at the inlet and outlet, the line is free from silt. It has never been necessary to dig up the pipe on account of root troubles, although it is very close to a row of trees. The line is buried about 3 feet, is straight, and nearly level. The water is clear at all seasons of the year. The poor joints are indicated by the coefficient 0.250.

No. 5, Experiment S-26.—12-inch jointed cement pipe, Irrigation Co. of Pomona, Calif.—Water for this irrigation system is secured from wells located on a gravel and boulder subterranean reservoir, locally termed a "cienaga." Dikes of impervious material cut off the flow in the gravel, forming a natural reservoir. The water from several wells is piped to one circular collecting chamber, while two pipes from this chamber permit the water to be conveyed to either one or both of two portions of the main pumping plant. One of these latter pipes 193 feet in length was tested. With a constant draft, the discharge of either pipe could be varied by head gates at the upper end of each pipe. Thus it was possible to vary the velocity in the pipe under test from 1.50 to 3.63 feet per second. For each observation the mean velocity of from 5 to 10 weighted floats was accepted as the velocity of the water between the intake chamber and a vertical riser pipe. These floats were made as follows: Small wire nails were thrust into an orange until it was of the same specific gravity as the water, showing little tendency to either float or sink. The pipe tested was under about a 4-foot head throughout its length, so that there was no tendency for the oranges to become heavier during passage through the pipe due to increasing water pressure, as is the case when a float of this nature is tried on a siphon pipe where the maximum head is much greater than the depth of the water in which the orange is tested while nails are being inserted. Of course, if a float in a pipe is too light it drags against the top of the pipe and if too heavy it drags along the bottom, in either case being impelled by velocities slower than the mean velocity in the pipe. It was thought that the round form of the orange would cause it to roll

easily whenever the current carried it against the periphery of the pipe, rather than lurch back into the current, as would a more irregular float. The maximum variation in time of any one float from the mean time of all of the floats was about 5 per cent. In connection with tests on pipe No. 7, floats of this type agreed with the velocity as determined by a well-made, contracted, rectangular weir 2.005 feet long within 1.2 per cent. At the intake a hook gauge in a stilling box determined the pressure head at the piezometer tube (type A) located 10 feet down the pipe. At the outlet a similar tube was held 1.6 feet in the pipe against the current. The pressure head at this tube was read in a water column beside the riser pipe. This pipe was laid in 1885 and appeared to be perfectly clean. As it is in an open field there is no chance of roots choking the interior. The nominal diameter was accepted in computing area and quantity of water (see No. 1, p. 25). The value of C_s varies with the velocity, from 0.244 to 0.278.

No. 6, Experiment S-33.—12-inch jointed cement pipe, San Antonio Water Co., Ontario, Calif.—This pipe lies between two division boxes and extends under a wash located north of Twenty-fourth Street and west of Euclid Avenue near Ontario. Though too short for experimental purposes, if low velocities are to be considered the 227.5 feet between the boxes is ample when the commercial velocity, nearly 6 feet per second, is obtainable. Water columns were used at both gauges. These were attached to piezometer tubes of type A, No. 1 being placed 7.7 feet in the pipe from the inlet chamber and No. 2 being held 2 feet up in the pipe from the outlet chamber. Velocities were computed from the mean time of four batches of fluorescein, timed from the instant of injection at the inlet to the mean between the first and last appearance at the outlet. Just four seconds (by test) was required for a given body of water to pass through the length of hose under a head of 1 foot. This head is of course the difference in elevation between the surface of the water in the chamber and the outlet of the hose. The nominal diameter was accepted in computing area and quantity (see No. 1, p. 25).

This pipe line was laid in 1911. The units are 2 feet long, made with a dry mix tamped into steel molds and afterwards washed on the inside with cement grout. The line is buried 2 or 3 feet and is straight but for a slight sag under the wash. The value of C_s , 0.322, shows the marked improvement in joints in pipe line laid in recent years.

No. 7, Experiment S-27.—12-inch jointed cement pipe, San Antonio Water Co., Ontario, Calif.—A straight, level reach of lateral pipe on Fourth Street, Ontario, was chosen for this test. Water enters the pipe over a division wall in a sand box and leaves it at the bottom of a similar sand box on the corner of Fourth and Euclid Streets. Piezometer tubes of type A were used at both ends of a reach 869.4 feet long. The pressure head at gauge 1 was read in a water column beside the sand box, while that at the outlet piezometer was read by a hook gauge in a stilling box attached to the piezometer by pressure tubing. Piezometer No. 1 was 4.7 feet from the inlet and No. 2 was 1.9 feet from the outlet. The mean time of six weighed orange floats like those described under No. 5 was used in computing the velocity of the water in the pipe. Accepting the mean area of samples of pipe of this size in the pipe yards of this company and comparing the ve-

locity as above determined with that found by dividing the discharge by this mean area, shows agreement with the mean of the two measurements of 1.2 per cent. The discharge was measured over a 2-foot contracted, rectangular sheet-iron-crested weir, with end contractions greater than $2h$, bottom contraction about 5 feet, and h less than one-sixth of the length of the weir. The water welled up from the bottom, so that velocity of approach was negligible. This pipe was laid in 1900. A comparison of the zone occupied by points representing this pipe with that of pipes 1, 2, 3, 4, 5, 9, 10, and 11 shows the progress made since the early eighties in the matter of smoother pipe pipe interiors and better joints, the value of C_s for this line being 0.345, an exceptionally high value for "dry-mix" pipe.

No. 8, Experiment S-53.—12-inch jointed concrete pipe, J. W. Crane private lateral near Oakdale, Calif.—From one of the laterals of the Oakdale irrigation district water is conveyed down a gentle hillside to the fields by means of a concrete pipe line. A reach 1,850.8 feet long was chosen for test, between the intake and an outlet hydrant in a riser pipe. The reach has one gentle curve in horizontal alignment and a slight sag near the far end. Water columns were used for both gauges, which were attached to piezometer tubes of type A. No. 1 was placed 4.4 feet down the pipe from the intake chamber, while No. 2 was thrust up into the line 6.4 feet from the riser pipe. Gauge No. 2 was a glass tube, while gauge No. 1 was a hook gauge noting the surface of the water in a stilling box. Thus a correction for capillarity was necessary in computing the elevation of the water column for gauge No. 2. Between the inlet and the second gauge are 21 riser pipes each 1 foot high, capped with a hydrant. The interior of the pipe was examined through several of these hydrants and found to be clean of silt, but with rough joints between the 2-foot units of pipe. The line was constructed by a man rather new in the business and the value of smooth joints was not appreciated as it now is in southern California. This is shown by the fact that C_s is but 0.245. Measurements of the pipe interior through these hydrants showed the average diameter to be 0.985 foot or that the area of the pipe was about 97 per cent of the area of a 1-foot pipe. The measured area was used in computations. Velocities were determined by injecting saturate solution of potassium permanganate into the upper end of the line and observing the first and last appearance of the color at an open hydrant 55 feet beyond the hydrant at gauge No. 2. A few small leaks were evidenced by moist ground, but the use of color in determining velocities automatically takes care of any correction for such leaks, the velocity of the color dropping in proper proportion and at the proper time as each leak is reached.

No. 9, Experiment S-24.—16-inch jointed cement pipe, Irrigation Co. of Pomona, Calif.—A second reach of the same main pipe line discussed as No. 10 was tested between boxes 91 and 92. This part of the line runs diagonally under an orange grove, but, although it was laid in 1883, roots have never interfered with the flow of water. It is straight, on a gentle down grade, and buried about 2 feet. There was one riser pipe in the reach tested. The nominal diameter was accepted in computing area and quantity of water (see No. 1, p. 25). Except for run 1, both gauges consisted of hook gauges in stilling boxes, No. 1 being attached by pressure tubing to a brass piezometer of type A, located 16.2 feet down the pipe line, while gauge No. 2 records the

elevation of the water in a delivery box 785.1 feet from gauge No. 1. For run 1, readings were taken by a plumb bob attached to a steel tape and allowed to scratch the water surface in the riser pipe at gauge 1. Water entered and left this riser pipe in the same straight line, so insuring that there was practically no loss of head within the riser (see No. 1). Examination of the inlet and outlet of this line indicated that there was no deposit upon the surface of the pipe. The mean time of two batches of fluorescein was accepted in computing the mean velocity of the water. The capacity of this line is about as indicated in Table 6.

No. 10, Experiment S-22.—16-inch jointed cement pipe, Irrigation Co. of Pomona, Calif.—This reach of pipe, laid in 1883, comprises part of a main trunk line conveying water from the pumping plant to minor pipe laterals. A straight section between boxes 36B and 37 was chosen for test. Box 36B is a single piece of riser pipe set directly over a rough hole in the trunk line about 8 inches square. The surface of the water in the riser was quiet so that hook gauge readings could be taken directly, no stilling box being necessary. Gauge and piezometer No. 2 were like those described under No. 9, the piezometer tube being held 3.2 feet up the pipe line against the current. The water was clear and no sediment in the pipe was seen through the hole at box 37B mentioned above. The pipe is on an even down grade, at no place under more than 3 feet of head. From three to five batches of fluorescein were timed for each run of water and the mean time was accepted in computing the mean velocity of the water for that particular observation. In order to secure runs at varied discharges it was necessary to return to this pipe from day to day and take an observation at the discharge then carried. The regimen of flow for each run was thus fully established. The nominal diameter was accepted in computing area and quantity of water (see No. 1, p. 25). The line is well laid, in comparison with other 1883 pipes, the value of C_d being about 0.304.

No. 11, Experiment S-25.—16-inch jointed cement pipe, Irrigation Co. of Pomona, Calif.—Immediately upstream from the reach of pipe discussed as No. 10, a section of the same 16-inch pipe, 1,897.6 feet long, between a masonry division box and delivery box 36B was available for test. It was practicable to secure but one observation on this line, however, for the reason that the pipe was full at the intake end only when the maximum amount of water then needed was flowing. The nominal diameter was accepted in computing area and quantity of water (see No. 1, p. 25). A hook gauge in a stilling box was used at the upper end. The stilling box was attached by pressure tubing to a piezometer tube of type A, thrust 8.4 feet down the pipe line. Gauge No. 2 of this reach was gauge No. 1 of reach No. 10 (for description of which see this page). This pipe is laid on a gentle down grade with one S curve in horizontal alignment as it is carried around a residence. At no point is it under more than 3 or 4 feet of head. Examination at inlet and outlet showed this pipe to be free from sand or deposits. The water is clear at all times, being pumped from a subterranean boulder reservoir (cienaga). A glance at Plate VI shows that the loss of head in this reach is practically identical with that in the adjoining reach (No. 10), upon which several observations were possible. The value of C_d is 0.306.

No. 14, Experiment S-58.—18-inch jointed cement pipe, Edwards private line, in Oakdale irrigation district, Calif.—Water for irrigation is conveyed across a depression from a main lateral of the Oakdale district to a knoll, in a plain cement-pipe inverted siphon 1,283.6 feet long, subject to a maximum head of about 11 feet. The pipe was made on the ground by the owner of the farm, aided by a man with a small amount of practical knowledge of pipe making. There is one 12-inch standpipe and one 12-inch valve near the low point. As both inlet and outlet of this line were submerged and it was not possible to vary the discharge to secure much variation in the velocity, practically all of the line was used in the experiments. Water columns attached to piezometer tubes of type A were used at both ends of the reach. Piezometer No. 1 was set 5.1 feet down the pipe from the intake chamber and No. 2 was thrust upstream from the outlet chamber a distance of 7 feet. Velocities were determined by the use of a saturate solution of potassium permanganate, injected at the inlet and observed at the outlet of the siphon. The nominal size of the pipe was accepted, as it was not feasible to secure measurements of the pipe itself.

From the fact that the value of C_s is very low, about 0.254, the writer would judge that sediment has obstructed this pipe more or less.

No. 15, Experiment S-56.—18-inch jointed cement pipe, Batdorf line, Oakdale irrigation district, Calif.—Irrigation water is conveyed from one open-channel lateral to another down a gentle hillside and across about 600 feet of level field by means of an 18-inch cement pipe made of jointed units each 2 feet long. There are four vertical standpipes rising above the hydraulic gradient on the total length of about 2,500 feet. Examination of the pipe at these standpipes showed that the line was full of water only through about the last 700 feet. A reach was chosen from a standpipe to the outlet, a length of 582.3 feet. A tube of type A was dropped down the standpipe and carried by the current 2 feet down the pipe. A similar tube was thrust 21 feet up the pipe from the outlet. Gauge No. 1 was a water column in a glass tube, while piezometer tube No. 2 was connected with a stilling box and the surface of the water determined by a hook gauge. The velocity was determined with a solution of potassium permanganate, timed from the standpipe to the outlet. As it would have been a difficult matter to determine the moment of injection down a standpipe 10 or 15 feet high above the pipe line, the solution was placed in a corked bottle held in a sack made from a piece of fly screen which was wired to the end of a long one-eighth-inch iron pipe. The bottle was thrust down the standpipe and smashed against the bottom of the pipe line, thus releasing the color but retaining the glass within the screen. The line under the standpipe was clean of deposit, as nearly as could be determined by feeling with the iron pipe rod, and from the appearance of the outlet. The value of the friction factor would indicate this to be true. The pipe is straight, buried about 3 feet, appeared from inspection of the outlet to have good joints, and was probably in good condition. The value of C_s is 0.284.

No. 16, Experiment S-42.—20-inch jointed concrete pipe, lateral C, British Columbia Fruitlands Co., Kamloops, British Columbia, Canada.—The main canal on this project is concrete lined, skirting

the foot of a low range of hills and delivering water to the intakes of the cement-pipe laterals. This delivery consists of an iron head gate at the canal end of a tube through the canal bank. Water is discharged through the tube into a rectangular sand and pressure regulating box 4 by 5 feet and $4\frac{1}{2}$ feet deep.¹ The water leaves this concrete box over a weir crest and falls to the intake chamber of the pipe line. At the head of lateral C the weir is of heavy sheet iron, rectangular in form, 3.02 feet long, without immediate end contractions, but with a bottom contraction of 39 inches. In addition to the flow over the weir there was a small constant leak through the drain gate near the bottom of the weir wall. This leak was measured and added to the flow over the weir for any particular run of water. A reach of pipe 1,116 feet long was chosen for test between a stand-pipe located 99 feet from the intake and a division box. The pipe was straight in horizontal alignment but wavy in the vertical plane, having two summits, each protected by standpipes. At low points of the profile the pipe is provided with blow-off valves. The maximum pressure on this pipe is due to a head of about 15 feet at the low points. Water columns attached to piezometer tubes of type A were used for both gauges. Tube No. 1 was dropped down a stand-pipe and allowed to be carried 3 feet down the pipeline. Tube No. 2 was thrust 1 foot upstream into the pipe line from the wall of the division box. The internal size of the pipe was determined by measuring two diameters on each of 10 pipe units remaining from the original construction. The mean area of these units was accepted as the internal area of the pipe line. Each unit was 2 feet in length. They were made by the "dry mixture" process and afterwards washed with cement grout. The writer was informed that extreme haste was used in laying the pipe and that the joints are very rough internally. This would account for the heavy friction loss in this pipe. Examination of both inlet and outlet indicated that this pipe was free from gravel or other débris. At the time of these tests the water was murky from recent rainstorms and the spring thaw, but during most of the irrigation season the water is clear. The value of C_s is about 0.255.

No. 17, Experiment S-46.—20-inch jointed concrete pipe, Bishop lateral, British Columbia Fruitlands Co., Kamloops, British Columbia, Canada.—Irrigation water is diverted from the main concrete-lined canal by a tube through the canal bank, discharging into the sand and weir box shown on Plate II, figure 1. From this weir the Bishop lateral, an underground pipe line, leads down a steep hillside to a point near the bank of Thompson River, thence paralleling the river. A reach of pipe between a vertical air pipe and a turnout box was chosen for experiment. The airpipe was located about three-eighths mile from the weir shown in the plate, while the turnout was 777.1 feet beyond the air pipe. Water columns attached to piezometers of type A were used at both ends of the reach, No. 1 being set 4 feet down the pipe line from the air pipe and No. 2 being thrust 1.3 feet upstream into the pipe line from the turnout. The pipe is gently curving in horizontal alignment and appears to follow the river grade in profile. If there is a sag in the profile it is too small to be noticeable to the eye. Examination of the line when no water was flowing showed the interior to be clean of deposit, but typically

¹ Described in "Irrigation Practice and Engineering," Vol. III, p. 368, B. A. Etcheverry, New York, 1916.

rough to the touch in the usual washed-cement pipe way. The discharge was measured over the rectangular, contracted weir shown in the plate (fig. 1). The crest is 3.02 feet long, the end contractions each 1 foot, and the bottom contraction more than 3 feet. For two observations the end contractions were very slightly less than twice the depth on the weir crest; for the others the end contractions exceeded twice the depth. Elevations of the water surface above the weir crest were determined with the hook gauge shown in the stilling box. The mean inside area of the pipe line was taken as the average area of 10 samples of the pipe remaining from construction. This area was 2.106 square feet, while the area of a true 20-inch pipe is 2.182 square feet. Thus this pipe is 3.5 per cent under size. The velocity of the water in the pipe was found by dividing the discharge in second-feet by the area of the pipe in square feet. This line was laid in 1911, thus being in its fifth year of operation at time of test. The coefficient $C_s = 0.313$.

No. 18, Experiment S-60.—20-inch jointed reinforced concrete pipe, Temescal Water Co., Corona, Calif.—Water for irrigation and domestic use is conveyed through 27,000 feet of plain concrete pipe flow line 22 inches in diameter and over 15 depressions which require inverted siphons.¹ Of these, 13 are of reinforced concrete, 20 inches in diameter. One of the longest of the siphons, about 4 miles from Corona, was chosen for experiment. Open standpipes occurred near both inlet and outlet of the siphon. Water columns attached to piezometer tubes of type A were used at both ends of the reaches chosen. For observations 1, 2, and 3, piezometer tube No. 1 was thrust 9.8 feet down the line from the standpipe at the inlet. For observations 4 and 5 a hole was tapped in the top of the concrete pipe 101.7 feet from the intake manhole and the piezometer tube thrust 6 feet farther down the pipe. For all observations piezometer No. 2 was set in the pipe 0.8 foot upstream from a hole tapped in the concrete pipe 98.7 feet upstream from the manhole at the outlet. Velocities were ascertained by the use of solutions of potassium permanganate and of fluorescein. For observations 1, 2, and 3 the color was injected in the manhole at the inlet, while for observations 4 and 5 it was injected at the tap in the concrete pipe 101.7 feet from the manhole. For all observations the color was observed at the manhole near the outlet. This pipe was cast on the ground in units 3 feet long. For moderate heads a 1 : 2 : 4 mixture of cement, sand, and gravel was used and for higher heads the mixture was changed to a ration of 1 : 2 : 3. All units were "washed" with cement grout before being laid. This siphon is straight in horizontal alignment but is on practically one long double-reverse vertical curve, the maximum head being about 80 feet, while the total length from manhole to manhole is 2,273 feet. The water is very clear and this siphon is undoubtedly absolutely free from débris, as all sand must pass more than 15 other siphons before reaching this one, the flow line between this siphon and the next one upstream being but 300 or 400 feet long. One blow-off valve is located at the low point of the siphon. The pipe was laid early in the year 1911 and was thus about 5½ years old at the time of the experiment. So far as could be determined from the low standpipes, the joints were well smoothed and this pipe is probably

¹ Engin. Rec., vol. 64, Nov. 4, 1911, p. 526.

typical of present-day careful practice in the citrus groves of southern California where long, well-made units are being used. The value of C_s is 0.345.

No. 20, Experiment S-57.—24-inch monolithic pipe, Claveysiphon, Oakdale irrigation district, California.—As described under No. 28, the first portion of the Clavey siphon is 36 inches in diameter from the inlet to a "booster pump" which is used to force part of the water through 3,000 feet of 24-inch pipe to a point 8 feet higher than the inlet to the siphon. Tests were conducted on a reach 1,046.2 feet long between an air valve and a point 6.6 feet upstream from the outlet of the 24-inch pipe. Water columns attached to piezometer tubes of type A were used for both gauges. Velocities were determined with potassium permanganate solutions injected at gauge 1 and observed at the outlet. The color dragged out from 6.2 to 9.6 per cent of the time from moment of injection to the mean time of first and last appearance at the outlet, depending on the intensity of the injection. Although nominally a 24-inch pipe, the mean of 6 measurements made in the last 30 feet of the pipe indicates the actual diameter was 23.7 inches, which was used in computations on this pipe. This pipe was constructed with wood forms, both inside and out. The longitudinal ridges made by the cracks in the boards, the circular ridge at the end of one setting of the forms and cemented concrete scraps are shown clearly in Plate II, figure 2, which was photographed from a point about 20 feet in the pipe at the outlet end. The values of C_s are erratic, varying from 0.328 to 0.373.

No. 21, Experiment S-47.—24-inch jointed concrete pipe, lateral A, British Columbia Fruitlands Co., Kamloops, British Columbia, Canada.—A reach of lateral A pipe line 2,306.5 feet long was chosen for test. Water entered the pipe from a box similar to the one described under No. 16. Likewise the installation of the piezometers was identical with Nos. 16 and 17. The first standpipe was located 64.7 feet from the inlet of the pipe. Between the two gauges were located two turn-out boxes (not in use at time of tests), one 12-inch standpipe, and one waste valve. Water in the standpipe rose to the hydraulic gradient. The writer had been notified that the pipe was partially filled with gravel from the hillside above the main canal. A heavy rainstorm had eroded the hill, filled the main canal near the inlet and regulating box with gravel, and washed some of the latter into the pipe line. The ratio between the measured size of several samples of this pipe and the true area of the water section was found in the following way: For one particular observation, the velocity of the water through the reach was determined with two injections of color—one permanganate and one fluorescein. These agreed within 2 seconds in an elapsed time of 1,800 seconds. The quantity of water was determined by hook-gauge readings on the 3-foot contracted weir at the pipe inlet.

The area was then found by solving the equation $A = \frac{Q}{V}$. The area thus found was 2.754 square feet or 87.5 per cent of the nominal area of a 24-inch pipe and about the equivalent of the area of a pipe 23.5 inches in diameter. The mean value of C_s is 0.252.

No. 22, Experiment S-61.—30-inch jointed concrete pipe, Temescal Water Co., Corona, Calif.—Water for irrigation and domestic use is conveyed over a shallow depression by a siphon pipe 1,028 feet long, inserted between an open concrete-lined channel in sandy soil and

a round pipe flow line. The siphon pipe is made of precast units, each 3 feet in length. The pipe is practically straight in both horizontal and vertical planes, the maximum head being about 8 feet. This line was constructed in 1911, being thus in its fifth year of operation at the time of the experiment. It carries water throughout the year. A reach was chosen for test between a point 79 feet from the intake chamber and a point 69 feet upstream from the outlet manhole. Water columns attached to piezometers of type A were used at both ends of the reach. Velocities were determined by the use of solutions of potassium permanganate, injected at gauge No. 1 and observed at the manhole beyond gauge No. 2. Measurements of the initial pipe section at the intake chamber showed the diameter to be 2.49 feet, or 0.01 foot less than the nominal diameter.

No. 23, Experiment S-34.—30-inch Jointed Reinforced Concrete Pipe, "D₁ Line", Umatilla project, United States Reclamation Service, Oregon.—Water for irrigation is conveyed across the depression near Hermiston, Oregon, in a 30-inch pipe laid in sections, each 4 feet long.¹ This line was constructed in the winter of 1909-10 and tested for friction losses in 1911 by Mr. H. D. Newell.² The writer conducted tests on the same reach of pipe during the season of 1915. See No. 12a (page 77) and No. 24a, for pipe description. Thus while comparatively new when first tested it had been in use nearly six seasons when these experiments were made. The pipe units were each 4 feet in length, cast in wood forms that had been coated with No. 26 sheet steel. The mixture and wash coating is described under pipe No. 32, page 41. Gage No. 1 was a piezometer tube of type B inserted into the water section of the pipe through a stuffing box, located above the valve A in figure 3, Plate 2. Newell appears to have used the pressure directly from a $\frac{3}{4}$ -inch valve set in the pipe line. The writer found so much air in the water column taken directly from this tap that he judged a piezometer tube, even of type B, would give more nearly the true pressure head (see discussion on page 15). This tube was connected with a mercury manometer. At the outlet a piezometer tube of type A was thrust 3.6 feet into the pipe, against the current. This tube was connected with a stilling box and the water surface in the latter was read by a hook gauge. The relation of the points plotted on Plate VI for the Newell tests (No. 24) and for those made by the writer (No. 23) indicate that the capacity of this pipe has diminished slightly. This was to be expected, for Newell speaks of deposits in the pipe after but one season while the writer's tests were made in the sixth season. Until July of each year the water for this pipe comes directly from the Umatilla River, through about 4 miles of open canal, the last reach of which discharges in a direct line into the pipe intake. This river water, taken during the high-water period, would undoubtedly contribute greatly toward silt and débris within the pipe as the maximum demand so far has not required a velocity in the siphon in excess of about 2.5 feet per second. Velocities were determined directly with solutions of fluorescein, the mean time of several batches being accepted in computing the mean velocity. This pipe is quite straight in horizontal alignment, while the vertical curves are long and gentle. There are five 6-inch valves and three manholes on the reach tested. Examination of the outlet indicates that the pipe is smooth and slimy inside. The color was injected into

¹ Eng. News, Feb. 16, 1911, Vol. 65, p. 208.

² Id. May 1, 1913, Vol. 59, p. 904.

the pipe line between the piezometer tube and the larger iron pipe (see Pl. II, fig. 3).

While but three observations were made on this pipe the conditions were very favorable for test. The values of C_s , about 0.330, are probably indicative of the silted condition within a smooth pipe rather than of the interior surface itself. (See values for Newell's tests, No. 24a.)

No. 26, Experiment S-51.—30½-inch jointed reinforced concrete pipe, Prosser pressure pipe, Sunnyside project, United States Reclamation Service, Washington.—Irrigation water is conveyed across the valley of the Yakima River by a siphon pipe of combination type. From the intake to a point 2,825 feet distant concrete pipe is used. The construction then changes to a wood-stave pipe 31 inches in diameter, which extends for an additional distance of 7,500 feet. A straight reach of the concrete pipe 2,276.3 feet long was chosen for test. Gauge No. 1, a water column attached to a piezometer tube of type A, was located about 500 feet from the intake, while gauge No. 2, a mercury column attached to a piezometer of type C, had been installed at the time of construction. A similar connection of type C had been placed near the upper end of the line, but was destroyed by the construction of a railroad crossing. It was necessary, therefore, to drill a new hole through the pipe and use a connection of type A. The velocities were determined by timing solutions of fluorescein, injected at gauge No. 1 and withdrawn into a white-lined pan from a secondary connection to the pipe line located near the head of the wood-stave portion of the line, beyond the end of the concrete pipe. The slight difference in the area of the wood and the concrete line was considered in computing the velocity in the concrete line alone. The mean area of the pipe was taken as the mean of the areas of six units of the pipe remaining from construction. It is quite certain that there was no sediment in the pipe, as the reach tested is on a continuous down grade and the operating velocities high enough to carry any débris on down to the sag of the siphon, which occurs in the wood-stave portion of the line several thousand feet beyond the concrete pipe. Examination of the line during the series of tests disclosed the scour at the upper end of the line (mentioned on p. 51), but showed a pipe free from slime or deposit at the upper end of the reach tested, and this condition undoubtedly held throughout the reach. The joints were not quite as nearly perfect as on the Victoria line (Nos. 30 and 31), and this probably accounts for some of the discrepancy in relative carrying capacities. As gauge No. 1 is located at an elevation approximately 20 feet higher than that of the outlet, it is readily understood that only velocities higher than that which necessitates a loss of head of 20 feet for the 2 miles of line beyond gauge No. 1 may be tested, because for all lesser velocities the pipe is not full at gauge No. 1. All concrete lines that serve as the intake ends of combination pipes are thus not subject to a complete test throughout a range of velocities, say, from 1 foot per second up, but can only be tested for the higher velocities.

The concrete pipe was made in 4-foot lengths with an exceedingly wet mixture of 1 part cement to 6 of gravel. All gravel passed a quarter-inch mesh screen. Steel forms coated with a particularly

heavy brick oil gave a smooth surface to the interior of the pipe. The concrete was tamped into the molds, and just before the initial set was retamped by a finisher, settling in the forms about 3 inches.

This line was designed by use of the Kutter formula, with a value of n taken as 0.013. The maximum capacity of the whole siphon was computed as 26.6 second-feet; but, whereas 29.39 second-feet was sent through the pipe during observation No. 2, this discharge practically filled the intake chamber and may be taken as the maximum capacity of the pipeline at the present time.

Since there is a long stretch of wood-stave pipe beyond the concrete pipe, each slight change in the velocity through the latter made a great change in the heights of the piezometer columns. A velocity of 4.88 feet per second was the lowest that could be tested, as it developed but a slight pressure head at the upper end of the reach. The velocity for maximum capacity was 5.78 feet per second. Thus the range of velocities feasible was rather short. Reference to Plate VI shows that, while consistent, the arrangement of the observation points indicates a very high exponent of V , namely, 3.18. Had the full range of velocities—between, say 1 foot per second and 5.78 feet per second—been possible of test, the points of observation might have more nearly compared to a slope of 2. Otherwise the conditions of experimentation appeared very good, and the writer is at a loss to explain the behavior of the points.

The friction factors, by the same token, vary, the coefficient C_s changing between 3.86 and 3.43, while from the appearance of the pipe interior it should have been about 0.360 for all observations.

Nos. 28 and 28b, Experiment S-54-55.—36-inch monolithic pipe, Clavey siphon, Oakdale irrigation district, California.—The Clavey siphon of this district, built in 1912, is of unusual construction. Water from an open channel lateral is conveyed 3,000 feet across a swale in a 36-inch reinforced concrete pipe, built in place. The outlet end is a few feet lower than the inlet. Thus far the construction is as usual.

Near the bottom of the swale, a few hundred feet before reaching the outlet, water from this pipe may be diverted through a booster pump. The energy of the total flow in the 36-inch line is used to pump a part of this same water through an additional 3,000 feet of 24-inch pipe to a point about 8 feet higher than the inlet of the siphon..

Both parts of this siphon were constructed in the same manner. Wood forms were used for inside and outside surfaces. This construction usually gives longitudinal ridges in the concrete where each crack between boards occurs and more or less irregularity in the surface at the abutting sections. This is brought out in Plate I, figure 1, and Plate II, figure 2. The mixture used was 1 part of cement to 6 parts of gravel. The resulting concrete is not first class, there being several leaks in the siphon. Most of these leaks occur at the joints between abutting ends of pipe sections. Two reaches of the 36-inch pipe were chosen for tests, No. 28b being 1,266 feet long and No. 28 being 1,933.6 feet long, but including all of reach No. 28b. Two lengths were tested, as the inlet end of the pipe was not completely filled during observations 1 to 3, inclusive, because of the small quantity of water, and the fact that the booster pump was not in operation, the longer reach of pipe being tested when the booster

pump was lifting water to the outlet of the 24-inch pipe. On reach No. 28^b a water column was used as gauge 1 and a mercury manometer as gauge 2. On reach No. 28 the water column was moved 667.6 feet nearer the inlet, but the mercury manometer remained the same as before. Air troubles at gauge 1 were minimized by the device shown in Plate V, figure 1. Piezometer tubes of type A were used for both gauges, No. 1 being slipped into the pipe through a one-eighth-inch wrought-iron nipple, while No. 2 was thrust down an air valve. Velocities were determined by timing fluorescein from its injection at gauge 1 to its appearance at gauge 2. For drawing off the colored water a "gooseneck" of one-fourth-inch brass pipe was inserted down the air valve and the color detected in a white-lined pan.

For some reason that the writer is not able to explain the friction factors are erratic and inconsistent.

No. 29, Experiment S-36.—36-inch jointed reinforced concrete pipe, Deer Flat Forest pipe line, Boise project, United States Reclamation Service, Idaho.—Water for irrigation is conveyed across a wide depression, just below the dam of Deer Flat Reservoir, in a concrete siphon pipe 8,575 feet long and 36 inches inside diameter.¹ As shown in Plate IV, figure 1, this line is straight in horizontal alignment and without vertical curves other than two gentle bends at the bottom of the slopes near the inlet and outlet. The maximum head is about 70 feet.

The pipe units, 6 feet in length, were cast on the ground in steel forms. A very wet mixture of 1 part cement to 2½ parts sand and 3 parts well-graded gravel resulted in a dense concrete. The shell is 3 inches thick, reinforced with five-sixteenth-inch wire. As shown in the plate, the joints were made with reinforced collars, each 3 inches thick and 8 inches wide in addition to the usual bevel and taper. The joints were calked on the inside with great care, the mixture used being 1 part cement to 2 of sand and tempered with hydrated lime in the proportion of 10 per cent of the cement by volume.

A reach of this pipe 7,282 feet long from the foot of the first slope to the outlet was chosen for test. Gauge No. 1 was a mercury manometer attached to the pipe at a small hole through a cast-iron manhole cover. At the outlet a piezometer tube of type A was thrust 2 feet into the pipe, and the pressure head conveyed by tubing to a stilling box within the outlet chamber, the elevation of the water in the box being determined by a hook gauge.

Unfortunately, in 1915 it was not feasible to vary the discharge through the pipe, so only one observation could be made. The velocity of the water was determined by accepting the mean of five batches of fluorescein, injected at gauge No. 1 and observed at the outlet. Accepting the mean diameters of 6 units of pipe remaining from construction, 2.999 feet, as the mean diameter of the pipe line, then the discharge was 24.6 second-feet, while the mean discharge over a weir below the outlet was 24.3 second-feet and the discharge as measured by a Price current meter, using the integration method, was 24.57 second-feet, and using the 0.2 and 0.8 depth method was 25.15 second-feet (see Table 2, p. 18).

¹ Engin. News, Aug. 8, 1912, vol. 68, p. 248.

The large pool just above the 10-foot Cipolletti weir was cleared of sand just prior to the experiments. The end and bottom contractions were equal to about twice the depth of water over the crest. The velocity of approach was about 1 foot per second. More exact figures were not feasible, due to shape of pool. The current-meter measurements were made by the hydrographer of the project simultaneously with the reading of gauges and the passage of the color in the pipe.

During the summer of 1917 the writer again visited this pipe and made additional tests on approximately the same reach of pipe. There being an abundance of water it was feasible to vary the discharge through the pipe and thus secure tests at various velocities. Gauge No. 1 was attached to a piezometer of type A while the piezometer at gauge No. 2 was very similar to that in the 1915 tests, but a glass gauge tube was used instead of a stilling box.

The velocities were determined by the travel of fluorescein solutions, which were timed from the intake of the siphon to the outlet. The average value of C_s for all the tests was 0.395. The high velocities probably assure a pipe free from sediment and the conditions at the intake are such that no gravel or heavy detritus would enter the siphon. As may be seen from the photograph, this pipe is exceptionally straight and under most favorable flow conditions. The writer would consider the coefficients found as verifying a working coefficient of 0.370 for glazed pipe under average conditions of curvature.

No. 30, Experiment S-49.—42-inch jointed reinforced concrete pipe, Victoria Aqueduct, siphon No. 1, Vancouver Island, British Columbia, Canada.—A pipe line quite typical of present-day high-grade construction has recently been built to convey water for municipal purposes from Sooke Lake, a mountain reservoir, to Humpback Reservoir, about 10 miles from Victoria, British Columbia.¹

This line, 27.3 miles in length, follows the hydraulic gradient as a flow line with the exception of 6 inverted siphons. The slope throughout is 0.001 foot per foot or 1 foot fall per thousand feet of length. Slightly more than one-half the line is curved. The pipe units are of the lock-joint type, each 4 feet long and exactly 42 inches in diameter. The shell of the flow line is 3 inches thick and that of the siphons $4\frac{1}{2}$ inches thick. The maximum head on any of the siphons is 90 feet. The flow-line pipe is reinforced with triangular mesh wire and square steel bars are used in the pressure units. The concrete, a "wet mix," composed of 1 part cement, 2 parts clean sharp sand, and 4 parts of beach gravel (maximum diameter three-fourths inch), was tamped into steel forms with a suitable slice bar, care being taken to force the coarse aggregate away from the forms, thus making a smoother surface.

The forms were well wiped with oil just prior to each pouring. After being filled they were placed in a steam room for three hours; the forms were then stripped and the pipe, resting on a base ring, again subjected to steam for an additional four hours. The interior surface of pipes made in this way is unusually smooth. At times there was small pitting, the cause of which remained obscure. If

¹ Engin. Rec., vol. 69, Feb. 21, 1914, p. 225; *id.*, vol. 72, Oct. 2, 1915, p. 406; *id.*, vol. 72, Oct. 23, 1915, p. 507. Can. Engr., July 23, 1914, vol. 27, p. 197; *id.*, June 10, 1915, vol. 28, p. 652. Western Engineering, vol. 5, Sept. 1914, p. 105.

too noticeable such a surface was wiped with thin mortar. Unless pitted no wash coat was applied.

The great amount of curvature was cared for by making three types of bevel-end sections and making the degree of curvature for each curve on the line such that one of the three types could be used with a maximum bend of 3° at each joint. This limit could be attained without inducing appreciable roughness within the pipe.

As shown in Plate VIII, figure 1, the various sections of pipe were fitted together on the ground without the use of cement, a "soup hole" being broken out of the top of each section just before fitting the following section. The outside of each joint was banked up with clay or stiff gravel to a point well above the spring line, in order to prevent loss of grout. In cementing the joints the invert was troweled from the inside. Then a band of spring steel 6 inches wide was tightened against the interior of the joint and grout poured into the soup hole from a coal bucket. When the grout had set the band was removed and any necessary smoothing done with a trowel. The writer examined the interior of this line and found the joints as smooth to the touch as the rest of the pipe. Although this line is not covered with earth, no expansion joints were inserted at the time of construction, it being thought that the great amount of curvature would automatically care for temperature changes. Experience with this line during the winter of 1916-17 shows that it would have been better to insert an expansion joint every few lengths of pipe.

Siphon No. 1, between manholes 4 and 5, was chosen for the major tests upon this line. It is longer than any of the other siphons and near enough to the gatehouse so that alterations in discharge may comparatively quickly reach the section under test.

Holes were drilled through the top of the pipe near each end of the siphon at such elevations that the pipe was completely filled at these holes regardless of discharge. Piezometer tubes of type A were thrust into the siphon through these holes. Water was turned out of the pipe while the piezometers were carefully placed on the inside. These tubes were connected with gauge glasses by means of which the pressure head was read directly in water columns.

Velocities were determined by fluorescein injected into the hole in the concrete pipe made for piezometer No. 1 and observed through the manhole in the flow line at the end of the siphon, beyond the hole for piezometer No. 2. A correction was necessary for the reason that the water did not fill the pipe for a few feet between gauge No. 2 and the manhole. Data for this correction were carefully taken with the level at the time the levels were run for the determination of the loss of head.

As stated in the discussion under No. 54a, page 86, there is a weir just above the intake to the pipe line. The crest is about one-fourth inch thick, rounded over on a radius equal to about one-half the thickness of the plate. Water entered the chamber above the weir from one side, making an indeterminate condition of approach velocity. However, a float gauge was read for each run of water and the discharge computed by the Francis formula. The comparison of the velocity in the siphon pipe as computed from this weir discharge and as determined by the direct timing of color is given in Table 2, page 18. It is to be noted that, for all runs, the velocity by direct measurement is greater than as computed by weir discharge.

In other words, as is to be expected from the conditions, the weir discharges more water for a given head than a standard Francis weir would have done. As mentioned above, the velocities used in the computations in tables 3 and 4 were all based on the color method.

The mean diameter of this pipe, found by measuring two diameters on each of nine pieces remaining from construction is 3.50 feet, agreeing with the nominal diameter. All things considered, the writer regards this series as among the best, due to the very favorable conditions for experimentation. The value of C_s is about 0.375 and may be taken as for a very smooth pipe with an excess of curvature.

No. 31, Experiment S-48.—42-inch jointed reinforced concrete pipe, siphon No. 5, Victoria Aqueduct, Vancouver Island, British Columbia, Canada.—This series of tests was conducted on the last of the siphons on this pipe line, siphon No. 5, located between man-holes 67 and 68. The same general discussion applies to this series as to No. 30. This siphon is much shorter, and in consequence the series should not be as reliable as No. 30. As shown in Plate V, figure 3, the siphon pitches down a steep grade, thence extends horizontally over a concrete trestle, thence climbs a steep hillside to the outlet manhole (in the foreground).

The values of C_s being around 0.390 would indicate a higher capacity than the observations on pipe No. 30, but those should be accepted over the tests on siphon No. 5.

No. 32, Experiment S-35.—46-inch jointed reinforced concrete pipe, R_1 siphon, Umatilla project, United States Reclamation Service, Oregon.—Water for irrigation is conveyed across a wide valley, from one open channel to another, by means of an inverted siphon pipe 9,830.8 feet long and subject to a maximum pressure head of 110 feet. It was constructed in the winter of 1909-10. The joint units are 8 feet in length, reinforced with a spiral of five-sixteenth-inch steel wire wound round longitudinal rods (Pl. VIII, fig. 2). The concrete was mixed in a ratio of 1 part cement to 1.44 parts sand and 2 parts gravel. The units were cast in steel forms and afterward painted on the inside with a grout made by pouring one-half bucket of cement into two-thirds of a bucket of water. This made a full bucket of a mixture of about the consistency of cream.¹

As shown in Plate VIII, fig. 2, the pipe is straight in alignment, while the profile is evident, with the exception of the deep sag across the lower lands, where the pressure head reaches 110 feet. Within the reach of pipe tested there are eight 6-inch valves, two 6-inch blow-offs, and four manholes, each 12 by 14 inches.

This line was tested by Mr. Newell in 1911 and again in 1912 (see No. 33*a*, p. 79). During the season of 1915 the writer conducted experiments on the same reach of pipe, between a valve 72 feet from the inlet and the outlet chamber, a distance of 9,774 feet.

For gauge No. 1 a mercury column was used, while for gauge No. 2 a piezometer tube of type B, extending into the jet at the outlet, led to a stilling box wherein the water-surface elevation was determined with a hook gauge. Two diameters were measured on each of 8 pipe units remaining from the original construction. The mean area of these units was 11.52 square feet, while the exact area of a 46-inch

¹ The details of manufacturing experience and costs covering a period of about three years are given in "Reinforced-Concrete Pressure Pipe on the Umatilla Project, Oreg., U. S. Reclamation Service," by H. D. Newell, Eng. News, vol. 65, Feb. 16, 1911, p. 208.

pipe is 11.54 square feet. The diameter of the pipe line was accepted as 46 inches.

The velocities for the various runs were determined by timing the passage of fluorescein from the point of injection, at gauge 1, to its appearance at the outlet. From 2 to 5 batches of color were used for each run. For any one run the elapsed time of the colors agreed within one-third of 1 per cent.

Reference to Plate VI shows that the curve for the 1915 experiments, when produced, passes through the midst of the points for Newell's tests made in 1911 and 1912. If this fact is truly indicative, then the capacity has not changed during the interim. This is reasonable, because the pipe is operated at a rather high velocity throughout the season and the feeder canal leading from the main canal to the intake is in a hard cemented gravel that would not contribute ravelings or silt, while the water itself comes from Cold Springs reservoir, and so is free from silt, except such as it may pick up in transit from the reservoir to the pipe. The clean condition of the pipe interior, where examined at the outlet, would indicate a pipe comparatively free from slime.

The mean value of the coefficient in the new formula, as determined from the Newell tests and our own, is 0.395, but it must be borne in mind that this pipe is practically straight, a rather unusual condition for a pipe nearly 2 miles in length.

No. 33b, Experiment S-60.—48-inch monolithic reinforced concrete pipe, Churn Creek siphon, Anderson-Cottonwood irrigation district, California.—In order to serve a certain acreage of land lying east of the Sacramento River, the flow of Churn Creek lateral is conveyed for about 4,300 feet in a round, monolithic siphon pipe extending from an open earth canal to a steel flume across the main channel of the river. (Pl. IV, fig. 2.) It was the original intention to extend the siphon under the bed of the river as a cast-iron pipe, but this plan was changed, so that at the edge of the deep-water channel the concrete pipe is turned vertically upward and placed in the first pier of a bridge across the river. This bridge supports a steel flume and the pipe discharges directly into the flume.

As shown in the plate, the siphon was constructed continuously, wood being used for both inside and outside forms. Though originally designed $4\frac{1}{2}$ feet in diameter, the pipe was constructed with a diameter of but 4 feet, owing to a reduction in the acreage to be served.

A single experiment for loss of head was made on this pipe in the summer of 1919. Piezometer tubes of type A were thrust into the siphon at inlet and outlet and the pressure head was carried over the banks to glass-gauge water columns. Piezometer No. 1 was thrust about 6 diameters (24.7 feet) down the inlet end and No. 2 was held 10 feet down the vertical outlet pipe located in the bridge pier. Between these piezometers there is a developed distance of 4,242.3 feet, so that a very material loss of head occurs for the commercial velocities—between 3 and 4 feet per second. The reach tested is practically straight in both vertical and horizontal planes, with the exception of the 90° bend as the pipe is turned upward in the bridge pier. The loss due to this bend is immaterial compared to the friction loss, and was ignored in the computations. The velocity of the water in the pipe was determined by injecting a solution of "Congo red" dye directly into the mouth of the siphon pipe, not into the pool in the

intake chamber. It was 1,091.3 seconds before the color appeared at the outlet and 84 seconds more before the last trace disappeared.

In computing the velocity the elapsed time is taken as from the moment of injection of the solution to the mean between first and last appearances of the color at the outlet. Being injected under a pneumatic pressure of 60 or 70 pounds against a static head of but 2 or 3 pounds, the "shot" of color leaves the color gun in but a fraction of a second, the lever handle of the valve being turned across the orifice slowly but continuously. When tried out in an open channel, where the injection can be watched, a great cloud of dense color, 3 or 4 feet in diameter, can be shot into the water, with an instantaneous opening and closing of the valve, merely by turning the handle through 180° .

As could be seen in the photographs from which the plate was made, each crack between the boards of the forms was clearly defined in the concrete structure. No opportunity has offered for examination of the interior of the siphon, but the velocities are such that little or no silt should collect in the pipe. The retardation factor of 0.313 confirms the recommendation of 0.310 for pipes of similar construction.

No. 35, Experiment S-40.—63½-inch monolithic reinforced concrete pipe, Simms Creek siphon, Sun River project, United States Reclamation Service, Montana.¹ Water for irrigation is carried over Simms Creek in a siphon pipe inserted between open channels.

This siphon was constructed in the winter of 1907-8. It was built in place, steel in 6-foot sections being used for the interior and wood for the outside forms. The inside was then washed with cement grout. From intake to outlet the pipe is 1,556 feet long and 5.3 feet in diameter.

Preparatory to the experiments conducted by the writer, piezometer connections of type C (fig. 4) were set in the zenith of the line at distances of 40 and 400 feet from the intake and 20 feet above the outlet. These will be referred to as taps 1, 2, and 3, respectively. At the time these taps were set the project manager inspected the pipe and found the interior in a very smooth, clean condition. So far as he is aware, the pipe had never been cleaned, although in its eighth year of operation.

The loss of head for the various velocities was measured between taps 2 and 3, a mercury column being used at tap 2 and a stilling-box type of water column at tap 3. In order to fill the pipe completely at tap 3 it was necessary to insert flashboards in the slots of the outlet structure. The velocity was determined by accepting the mean time of two or three batches of fluorescein. For observation 1 the color was injected at tap 2, but for the other runs the color was injected at tap 1. The first and last appearance was noted at the outlet of the siphon. Thus for all observations other than No. 1 the color traversed a reach of 379.5 feet longer than the reach between manometers, while for run 1 the color reach was but 20 feet longer. The line was designed for a capacity of 175 second-feet of water, based on a value of n in the Kutter formula of 0.012. Mr. C. P. Williams, project manager, stated to the writer that "The maximum amount that had been carried by the siphon was about 225 second-feet. At this time there was 255 second-feet diverted into the head of the canal and the loss between the head and the siphon was about 30 second-feet." Our experiments also bear out the fact that the

¹Eng. Rec., vol. 59, 1909, p. 716.

capacity is greater than a value of n of 0.012 would indicate. Air troubles in gauge No. 1 caused inconsistent results for this series, and for this reason full weight should not be assigned to the tests. The values of C_s range from 0.380 to 0.434, and the corresponding values of n from 0.0116 down to 0.0101. During the season of 1917 the writer again visited this pipe while it was carrying far more water than for any of the observations made in 1915, but the air troubles were even greater than before, so experimentation was considered out of the question. This pipe shows the need of "air chimneys" near the intake if maximum efficiency is to be reached.

No. 37, Experiment S-59.—120-inch monolithic concrete pipe, Whitney siphon, Los Angeles Aqueduct, California.¹—The Whitney siphon, on the Saugus division, is 955 feet long, 10 feet inside diameter, with a shell 9 inches thick, and is subject to a head of about 75 feet. It conveys water for municipal and irrigation purposes across a narrow canyon, between two flow-line tunnels. The sides of the canyon have a slope of about 3 feet horizontal to 1 foot vertical.

The pipe was constructed in place, smooth wood forms being used for both inside and outside surfaces.

The interior of the pipe was treated with a finish coat of rich cement mortar. The grit of the sand in this coat was very noticeable to the touch at the time of experiments in 1916.

A reach of the siphon pipe below the level of the floor of the flow-line at both inlet and outlet was chosen for test. Holes were drilled through the top of the shell and one-eighth-inch iron-pipe nipples, each 18 inches long, were cemented into the shell. (The hole for a one-eighth-inch pipe is nearly one-fourth inch in diameter.) Two piezometer tubes of type A, exactly alike in construction, were thrust into the pipe through the nipples. The tapering end of these tubes was made flexible by a small rubber-hose joint with the main tube, so that the current might hold each piezometer in the direction of flow by means of the flattened taper, like a vane.

The flow-line channel is tapered into the round section of the siphon pipe by means of transition sections at each end of the siphon. Between the transition sections and the flow-line sections manholes are placed at both inlet and outlet.

The tap for gauge No. 1 piezometer was 59.2 feet downstream from the manhole at the inlet, while the tap at gauge No. 2 was 61.1 feet upstream from the manhole at the outlet. The holes in each piezometer tube were 3.6 feet downstream from the taps in the pipe. This made the reach between piezometers 857.4 feet long. Water columns were used at both gauges.

The nominal size of the pipe was accepted in the computations. The velocities were determined by timing the passage of solutions of fluorescein, injected at gauge No. 1 and observed at the manhole beyond gauge No. 2, correction being made for the fact that the channel is not full for part of the distance between gauge No. 2 and the manhole.

Experience with this pipe showed that satisfactory tests can not be made on a reach of pipe that is relatively short, compared with the size of the pipe, especially for low velocities. The loss of head for

¹ Construction of the Los Angeles Aqueduct, Final Report, Los Angeles, Calif., 1916, pp. 210, 214. Engin. Con. July 3, 1912, p. 20.

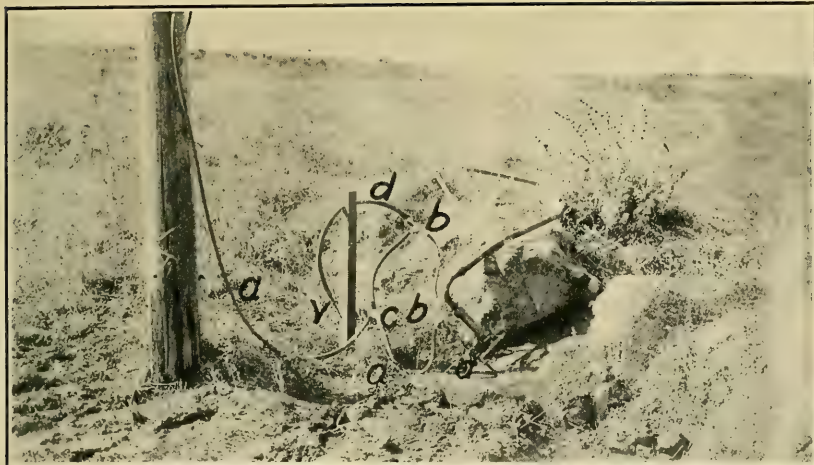


FIG. 1.—CONNECTION AT GAUGE I, CLAVEY SIPHON, OAKDALE IRRIGATION DISTRICT, CALIFORNIA. (PIPE No. 28.)

Note air trap and color reservoir. Gauge glass is on pole.



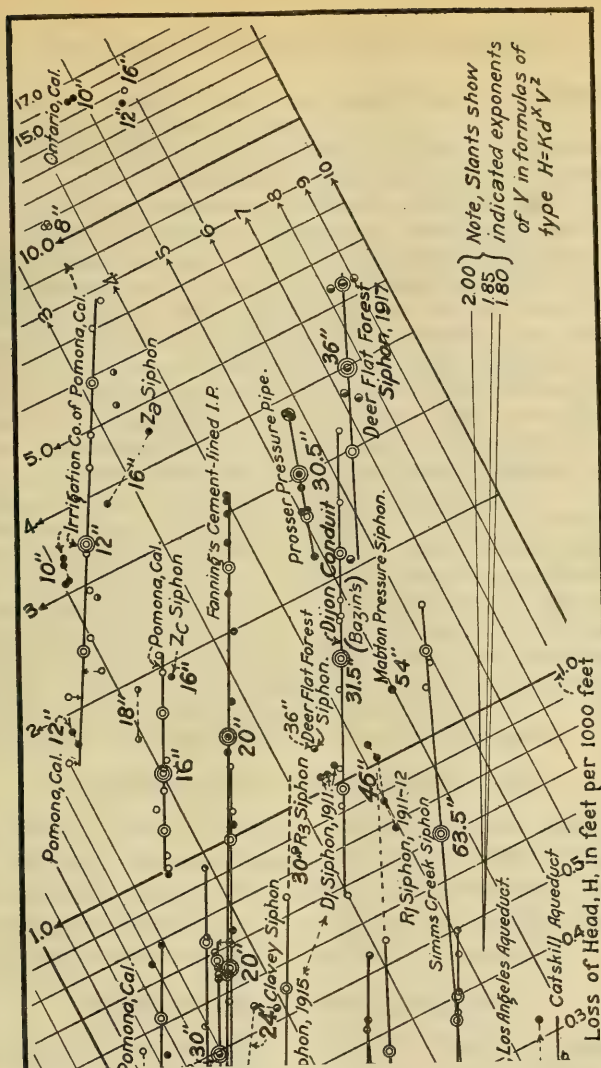
FIG. 2.—SIPHON NO. 1, VICTORIA AQUEDUCT. (PIPE No. 30.)

Mr. Ewing is standing at tap for gauge No. 1.

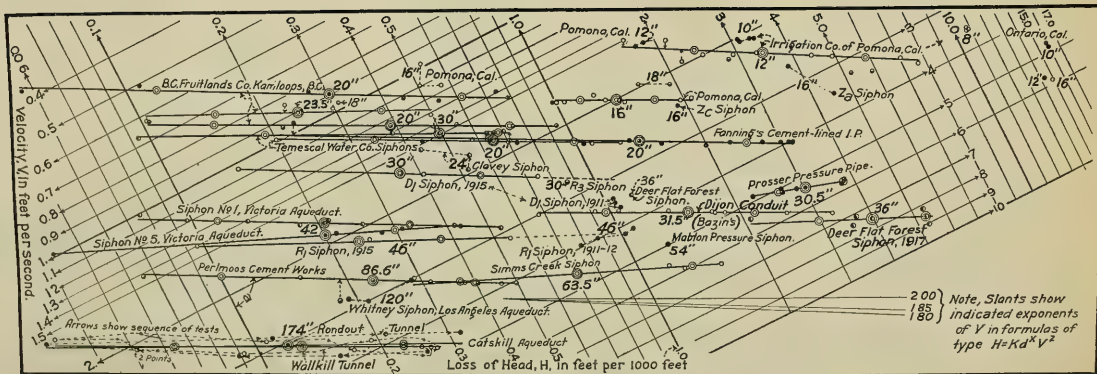


FIG. 3.—SIPHON NO. 5, VICTORIA AQUEDUCT. (PIPE No. 31.)

Note manholes and concrete trestle over creek. Wood trestle used during construction for conveyance of pipe units.



SHOWING OBSERVATIONS ON CONCRETE PIPES, RUNNING FULL.



LOGARITHMIC DIAGRAM SHOWING OBSERVATIONS ON CONCRETE PIPES, RUNNING FULL.

a low velocity in a large pipe is so small that it conflicts with the ordinary errors of experimentation.

For observation No. 1 (not included in Table 3) the water column at gauge No. 2 was 0.017 foot higher than the column at gauge No 1 for a velocity of 1.76 feet per second, whereas it should have been in the neighborhood of 0.070 lower. There was absolutely no error in the levels. Agreement between levels of the gauge glasses at the ends of the reach as developed by the wye level and as shown by the static pressure in the siphon with still water was within 0.001 foot. The writer can account for the discrepancy between the actual gauge heights (which indicated that there was a gain instead of a loss of head) and the heights that might be expected only by explaining that piezometer No. 1 is impinged upon by the water soon after pitching downhill at the intake of the siphon, while piezometer No. 2 is subjected to the current after the water has passed through 850 feet of 10-foot pipe, the last 200 feet of which are straight.

The observations on this pipe listed in Table 3 were made at velocities great enough so that a distinct loss of head was recorded, but there is probably some of the same error that showed the gain in head for observation No. 1. For this reason the writer does not accord any weight to this series, but does not wish to suppress the tests and uses them to emphasize the necessity of testing relatively long reaches of pipe in order that the actual loss of head may far overshadow the unavoidable experimental errors.

For experience on pipes of larger sizes see Appendix.

ANALYSIS OF THE EXPERIMENTAL DATA.

Water flowing under pressure, confined on all sides, probably follows a slightly different scheme as regards velocity distribution from that of water which but partially fills the conduit, thus having a surface exposed to the air. For this reason the results of experiments under these two conditions will be discussed separately.

FLOW IN PIPES UNDER PRESSURE.

It has come to be generally understood that the relationship of friction loss to velocity within a given pipe of any material can be represented by the equation

$$H = m V^z \quad (12)$$

in which the values of z are as a rule between 1.70 and 2.00, although there are many records of experiments in which the value of the exponent z was in excess of 2.

For a series of pipes of the same general characteristics but of varying diameters the values of m follow the general equation

$$m = K d^x \quad (13)$$

Substituting in formula 12

$$H = K d^x V^z \quad (14)$$

This expressed logarithmically becomes

$$\log H = \log K + x \log d + z \log V \quad (15)$$

In Plate VI the loss of head per thousand feet of pipe, H , for each observation on concrete pipes, is plotted on logarithmic paper as an ordinate against the corresponding value of the mean velocity, V , as an abscissa. For a given series of observations the resulting curve represents equation 12 in its logarithmic form

$$\log H = \log m + z \log V \quad (16)$$

which is now recognized as the equation of a straight line where m is the intercept on the axis of H (which is the line $V=1$) and z is the tangent of the angle between the curve and the axis of V (indicated by α on Pl. VI).

A study of this plate, in connection with the descriptions of the various pipes, shows that pipes of the same structural characteristics follow a rather definite order of position on the plot. If all of the curves were of the same inclination to the axis V , then this order of position would be definitely and fully disclosed by a diagram in which the values of m are plotted on logarithmic paper as ordinates and the diameters of the pipes, in inches, are plotted as abscissas. The experiments upon some of the pipes, of necessity, covered such a short range of velocities that the curves indicate a slope quite at variance with that which would have probably resulted for more complete series. For this reason the writer has not projected the curves to an intersection with the axis of H , in order to determine the relative positions of the values of m . Obviously some system of weighting should be assigned to the various series and, in the study of experiments upon wood-stave pipe, an arbitrary weighting method was employed; but because there was some criticism of this procedure the writer hesitates to repeat it.

If all the pipes were made in the same manner, had the same interior surfaces, and were subject to the same hydraulic conditions, a law derived by the method of least squares should be the best and most accurate. This method of handling experimental data, however, ascribes all variation from a given law to errors, according to the probability of errors, whereas most of the variation from an average law of data on commercially made concrete pipes is due to inherent differences in the pipes.

For any given series of experiments upon the same pipe the method of least squares is applicable, in its simplest form; that is, by the center-of-gravity method.¹ This method was used in computing the individual formulas given in column 10, Table 4. The curve is represented graphically in Plate VI, where the center of gravity of all the points in any one series is shown as two circles around a center which is typical of the observation points for that particular series. That is, if the observation points are given as open circles,

¹ Described in Bul. 376, U. S. Dept. Agr., p. 50, and in Amer. Civil Engineers Pocketbook, 3d ed., New York, 1916, p. 847.

then the center is an open circle, and if its points are given as solid dots, then the center is a solid dot. The centers of gravity of the upper and lower zones for a given series are shown by two concentric circles. The straight line representing the curve for that series passes through these three points, and the equation for this line is the equation for that particular pipe, so far as the observations developed it.

On Plate VI are shown three lines indicating slopes for three values of z . The slope of 1.80 conforms to that of the Moritz formula and to the slope found by both Moritz and the writer for the flow in wood-stave pipes. The slope of 1.85 conforms to that of the Williams-Hazen formula, while the slope of 2 conforms to the slope in the original Chezy formula and has been adhered to by later authorities. The border lines of the plate are also drawn at the slope of 2 for ready comparison. The slope of 2 agrees with the belief, so long honored that it became an axiom but was later proved not necessarily true, that the loss of head must vary as the square of the velocity.

With the desire not to increase the number of already numerous formulas, Plate VI was studied, on a tracing made over 10-inch logarithmic paper, in connection with sets of parallel lines based on the above-mentioned definite slopes. On this basis it was obvious that a slope of 2 most nearly applied, not only for the average slope of the various curves, but also in following the zone for a given size pipe from one series through a range of velocities to another series at higher or lower velocities.

Accepting this value for z of 2 and recognizing that there are several typical concrete surfaces, it is now necessary to determine x , the exponent of d and a set of coefficients, K . Allen Hazen has stated,¹ in discussing the Saph and Schoder experiments:

It has seemed to the writer [Hazen] that the most accurate value for x could be secured by comparing the results obtained for very small and very large pipes. Of course it is impossible to secure very large pipes with precisely the same kind of interior surface as obtained in very small pipes, but it seems safer to compare the results obtained from very large and very small pipes, even though their interior surfaces do differ somewhat in character, than to take the indications of experiments more closely comparable, but covering a shorter range.

It is to be borne in mind that Hazen was speaking of brass pipes less than 2 inches in diameter when he referred to "very small pipes." However, the reasoning was sound, and this suggestion has been followed by the writer. Concrete pipes were divided into four general classes, as discussed on page 7: (1) Old California pipes; (2) modern "dry-mix" cement pipe and wood-form monolithic pipe; (3) wet-mix cement pipe and average steel-form monolithic pipe; (4)

¹ Trans. Amer. Soc. Civil Engin., 51 (1903), p. 320.

glazed interior pipes. Class 3 was chosen from which to derive the value of x and of K_3 , using the 20-inch Temescal pipe (No. 18), supported by Fanning's experiments (No. 19) for the small size and the Catskill aqueduct 174-inch pressure tunnels for the large size (Nos. 39 and 40). This class was chosen because the range between comparable surfaces was greater than for any of the other three classes, of which classes 1 and 2 extend from 6 inches up to about 36 inches, and class 4 is represented by experiments on pipes from 30 to 63 inches only.

The experiments upon the 20-inch and the 174-inch pipes mentioned above were accepted as basic, partially because they were conducted upon relatively long reaches of pipe where conditions for experimentation were favorable, but for the most part because of their relative positions on Plate VI, as regards the positions occupied by points representing pipes which are known to have very smooth surfaces and pipes that are known to be rougher than modern practice will countenance, as well as lines that can be classed as "modern concrete pipe," neither exceedingly smooth nor "mortar-squeeze" rough.

From the centers of gravity for the 20-inch and 174-inch pipes, projections at a slope of 2 intercept the axis of H (line for $V=1$) at 0.2006 and 0.0125 respectively, from which values of m for their respective diameters, K is computed as 9.4 and x as -1.28 . Since x , the exponent of d , was accepted as -1.25 by Schoder and other authorities, and the writer did not desire to alter existing formulas unless the necessary change is radical, he also accepted -1.25 for x and recomputed K . The pivot for changing the slope from -1.28 to -1.25 should be for an average-size pipe rather than for a 1-inch pipe. A 42-inch pipe was accepted as about the average size; then substituting in formula 13,

$$m = \frac{9.4}{42^{1.28}}, \text{ or } \log m = \log 9.4 - 1.28 \log 42$$

from which $m = 0.07859$ for a diameter of 42 inches.

With this value of m and -1.25 for the value of x , substitution in formula 13 gives

$$0.07859 = K 42^{-1.25}, \text{ or } \log 0.07859 + 1.25 \log 42 = \log K.$$

or

$$\log K = 10.92443, \text{ from which } K = 8.4.$$

Making the final basic formula for pipes of class 3 read:

$$H = \frac{8.4 V^2}{d^{1.25}} \quad (17)$$

from which

$$V = 0.345 H^{0.5} d^{0.625} = 1.63 H^{0.5} D^{0.625} = 115 R^{0.625} S^{0.5} \quad (17a)$$

and since $Q = A V$, then

$$Q = 0.00188 H^{0.5} d^{2.625} = 1.28 H^{0.5} D^{2.625} \quad (17b)$$

Class 1.—From a study of the older San Antonio Water Co. and Pomona pipes of class 1, a coefficient of 14 was found for K_1 , making the formulas for this class read:

$$H = \frac{14 V^2}{d^{1.25}} \quad (18)$$

from which

$$V = 0.267 H^{0.5} d^{0.625} = 1.26 H^{0.5} D^{0.625} = 89 R^{0.625} S^{0.5} \quad (18a)$$

and

$$Q = 0.00146 H^{0.5} d^{2.625} = 0.99 H^{0.5} D^{2.625} \quad (18b)$$

Class 2.—Probably more than half the concrete pipes being laid at present in the United States are made locally, in 2-foot sections, by the "dry-mix" hand-tamped, cement-washed process in the west coast States. This type of pipe constitutes most of class 2. Throughout the irrigated portions of California nearly every town has one "pipe

For this class of pipes, a study of the newer Pomona and San Antonio Water Co. lines, supplemented by an examination of lines and pipe units in other parts of California, lead to the derivation of 10.4 for the coefficient K_2 making the formula for this class read

$$H = \frac{10.4 V^2}{d^{1.25}} \quad (19)$$

from which

$$V = 0.310 H^{0.5} d^{0.625} = 1.47 H^{0.5} D^{0.625} = 103.5 R^{0.625} S^{0.5} \quad (19a)$$

and

$$Q = 0.00169 H^{0.5} d^{2.625} = 1.15 H^{0.5} D^{2.625} \quad (19b)$$

Class 4.—The experiments upon the Victoria Aqueduct, siphon No. 1 (pipe No. 30) were chosen as characteristic, because they are well supported on the conservative side by those on other exceedingly smooth finished pipes and the conditions for experimentation were so unusually favorable. The coefficient K_4 was found to be 6.7, making the formula for this class read

$$H = \frac{6.7 V^2}{d^{1.25}} \quad (20)$$

from which

$$V = 0.370 H^{0.5} d^{0.625} = 1.75 H^{0.5} D^{0.625} = 123.5 R^{0.625} S^{0.5} \quad (20a)$$

and

$$Q = 0.00202 H^{0.5} d^{2.625} = 1.37 H^{0.5} D^{2.625} \quad (20b)$$

EFFECT OF AGE UPON CARRYING CAPACITY.

In designing a pipe line of a given material and workmanship the engineer must not consider so much the capacity of the pipe when new but after a period of subjection to the local conditions that finally determine the interior of any pipe line. Deposits of mud, gravel, etc., will of course choke any pipe and will not be considered in the following discussion, though it may be well to state in

passing that accumulations of detritus do not occur at the low point in the profile of a siphon pipe, but will pass this point and precipitate at the base of the first steep upward pitch. They are thus, as a rule, beyond the reach of a flushing stream if the only blow-off is located at the extreme low point. For this reason it is advisable to place the main blow-off at the steep upward pitch and a small valve at the extreme low point in order that the pipe may be completely drained.

It has become an accepted fact that cast-iron and steel pipes carry less water for a given loss of head from year to year. So far as evidence is obtainable, wood-pipe interiors remain about the same, though occasionally a pipe is found with interior growths of *Spongilla*.

Moritz writes:

The effect of age on concrete pipe is not known, but it is customary to assume that the carrying capacity does not decrease, as there is no reason to suppose that it should.¹

Bishop states that there appears to be no deterioration of capacity in cement-lined pipes laid in 1871-72 for municipal purposes. His examination was made 38 years later.²

The city authorities of Grenoble, France, comment favorably upon the condition of a concrete pipe after 15 years' service, mentioning a slight calcareous deposit one-sixteenth inch thick.³

At first thought it would appear that cement or concrete, subjected to water free from erosive material, should retain the original surface, with the possible exception of sliming, which may cut down the capacity from 10 to 15 per cent, but from which concrete surfaces are comparatively free.⁴

Examination of the interiors of many pipe lines supplemented by interviews with managers of water systems and a study of available literature show that the capacity may deteriorate, due to the following causes:

- (1) The invasion of rootlets from neighboring trees.
- (2) Scour from the water.
- (3) The accumulation of lime or other deposits.

In southern California experience teaches that pipe lines may be laid under citrus groves with no ill effects from roots, but that where the line is laid near black acacia, willow, pepper, or eucalyptus trees, rootlets will enter the pipe, not necessarily at the joints, if it is poorly made and poorly laid, and retard the flow. These trees are named in order, the acacia being the most destructive. Roots will not effect a dense, well-made pipe, with tight joints. (See Mr. Finkle's discussion on p. 95.)

Literature contains accounts of clay and concrete pipes being clogged with roots, particularly of the elm tree.⁵

¹ Working Data for Irrigation Engineers, p. 69.

² Experience with Cement Mains at Rahway, N. J. By Wm. Bishop, Pro. American Waterworks Assn. (1910), p. 217.

³ Can. Engr., Oct. 19, 1911, vol. 21, p. 455.

⁴ Water Works Handbook, by Flinn, Weston, and Bogert, New York, 1916, p. 290.

⁵ Eng. Rec., 1916, vol. 73, p. 460; *id.*, p. 514; *id.*, p. 688; *id.*, vol. 79, p. 36. Irrigation in Southern California, W. H. Hall, Sacramento, Calif., 1888, p. 495.

Concrete, under usual conditions, will withstand high velocities.¹ According to A. P. Davis, the following conclusions were warranted from his observation of velocities in concrete:

1. That where clear water can be made to glide over concrete without disturbing its velocity or abruptly changing its direction, there is no practical limit to the velocities that can be permitted without harm.

2. That concrete which is subjected to the impact of water under high velocity is rapidly eroded and that under such conditions the velocities must be very carefully limited.

The fact has been pointed out by C. H. Paul that concrete tunnels treated with a coat of water-gas tar, followed with two coats of coal tar, withstood velocities up to 64 feet per second without appreciable wear.² The experience with this feature of water flow, gained in making these tests, may be of value. The water conveyed through the Prosser pressure pipe (No. 26) contains many fine particles of hard, rough, basalt ravelings. This pipe is operated most of the time at much less than its maximum capacity, so that the water enters the intake in a very turbulent condition and rushes down the initial reaches of the pipe at a high velocity. At the intake the bottom of the pipe presents the appearance of having been subjected to a sand blast. All the finer materials in the concrete have been scoured out, clearly defining each hard pebble larger than about one-fourth inch in diameter. This scour has extended possibly one-eighth inch deep between pebbles. The degree of roughness diminishes from a maximum at the bottom to none at the mid-diameter; likewise diminishing with distance down the pipe until it was not noticeable about 150 feet from the intake. (See Mr. Newell's discussion on p. 100.)

A peculiar condition under which erosion may be expected was called to the attention of the writer in southern California. Unless pipe lines are laid on a smooth gradient, any sand in the water will wear out the bottom of the pipe where the latter goes over humps.

The obstruction of a pipe by lime deposit is mentioned by W. E. Condon.³ (See Plate I, figure 2.)

CAPACITY OF CONCRETE PIPES.

In the following pages the design of concrete pipes is considered with reference to carrying capacity alone. Structural features do not come within the scope of this paper, except as they affect the interior surface.

The total loss of head necessary in the conveyance of a given quantity of water will be the sum of the velocity head, h_v , the entry head, h_e , and the friction head, h_f , or its equivalent per unit length, less any velocity head, h'_v , that may be recovered as the water

¹ Safe Velocities of Water in Concrete, by A. P. Davis, Eng. News, vol. 67, Jan. 4, 1912, p. 20. Engin. News-Rec., vol. 80, p. 172. Concrete, Plain and Reinforced, by Taylor and Thompson, New York, 1917, p. 779.

² Use of Water-Gas and Coal Tar on Concrete Subjected to High Velocities of Water, by C. H. Paul, Reclamation Record, Jan., 1916, p. 46. Reprinted in Engin. Rec., Jan. 22, 1916, p. 108.

³ Original and Acquired Roughness of a 30-inch Cement Water Supply Conduit, Southern California, Engin. News, Jan. 9, 1908, vol. 159, p. 41.

approaches the pipe outlet at a velocity relatively high compared with the velocity in the open water below the outlet chamber. This total may be expressed by the formula

$$H_e = h_v + h_e + h_f - h'_v \quad (20)$$

where H_e has the significance shown in figure 1 and h_v , h_e , and h_f , and h'_v have the significance defined on page 51. The influence of gentle curves was included in the data upon which the formulas were based, so that an additional loss for slight bends or curves need not be considered in the design of the usual pipe on irrigation systems. If sharp bends can not be avoided, then an additional loss of head must be anticipated. The results of such tests as have been made on bends in pipes are given in standard works on hydraulics.

VELOCITY AND ENTRY LOSSES.

In designing pipes of small diameter and great length, the losses due to velocity and entry heads, h_v and h_e , are so small compared with the friction loss that they may be neglected. Otherwise they should be included in the allowance for total lost head.

It is best to consider the water above any intake as at rest. From this state of rest velocity must be created and increased to the mean velocity, V , existing in the pipe. The head, h_v , necessary to create a given velocity is shown in column 2, Table 5. The entry loss will be from $0.5 h_v$ where the pipe of standard size begins at a headwall and is without bell or taper mouth, to about $0.25 h_v$, for a rounded intake, and $0.05 h_v$ for a bell-mouth intake. In Table 5, column 3, is shown the amount of entry loss when taken as half the velocity head (column 2), and the sum of the entry and velocity losses is shown in column 4.

TABLE 5.—Mean velocity in pipe V , in feet per second, and head of elevation lost creating this velocity and overcoming entrance conditions, h_v and h_e , in feet.

1	2	3	4	1	2	3	4
V	h_v	h_e	$h_v + h_e$	V	h_v	h_e	$h_v + h_e$
<i>Ft. per sec.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Ft. per sec.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
1.0	0.016	0.008	0.024	5.0	0.389	0.195	0.584
.2	.022	.011	.033	.2	.420	.210	.630
.4	.030	.015	.045	.4	.463	.227	.680
.6	.040	.020	.060	.6	.488	.244	.732
.8	.050	.025	.075	.8	.523	.262	.785
2.0	.062	.031	.093	6.0	.560	.280	.840
.2	.075	.037	.112	.2	.598	.299	.897
.4	.090	.045	.135	.4	.637	.319	.956
.6	.105	.053	.158	.6	.677	.339	1.016
.8	.122	.061	.183	.8	.719	.359	1.078
3.0	.140	.070	.210	7.0	.762	.381	1.143
.2	.159	.080	.239	.2	.806	.403	1.209
.4	.180	.090	.270	.4	.851	.426	1.277
.6	.202	.101	.303	.6	.898	.449	1.347
.8	.224	.112	.336	.8	.946	.473	1.419
4.0	.249	.125	.374	8.0	.995	.498	1.493
.2	.274	.137	.411	.2	1.045	.523	1.568
.4	.301	.151	.452	.4	1.097	.549	1.646
.6	.329	.165	.494	.6	1.150	.575	1.725
.8	.358	.179	.537	.8	1.204	.602	1.806

Where the usual types of inlet and outlet structure are employed, with but little construction and consequent expense incurred for conservation of entry and velocity heads, it is recommended that the figures in Table 5 be used.

AIR IN PIPE.

Like all other lines, a concrete pipe must be protected by air valves against the accumulation of air at "summits" on the line. If this is not done the capacity will be reduced.

In addition to the air at summits it has been found that the capacity of a siphon pipe may be reduced by accumulations of air at the intake end. This accumulation may take place several hundred feet down the incline from the pipe entrance and manifest itself by a periodic "blowing back" of compressed air. The writer has seen two instances where the resulting conflict between air and water has burst the pipe.

Pipes taking water directly from reservoirs are, of course, not subject to these troubles, the depth above the intake being, as a rule, sufficient to insure filling of the pipe with water alone.

Mr. A. E. Ashcroft, of Vernon, British Columbia, Canada, in speaking of some 36-inch siphon pipes, says:¹

A large number of air valves at the upper ends of the pipes have been effective in reducing vibration and thumping when the pipes are discharging only partially full. (See also Mr. Finkle's discussion, p. 94.)

The best air outlet is probably a "chimney" rising above the hydraulic gradient. These vents may be from 1 to 36 inches in diameter, depending on the size of the pipe line, and small ones should be so assembled that they may be taken apart, as debris collects in such vents and must be periodically removed. Moritz suggests the area of the relief pipe be one-twentieth of that of the pressure pipe.²

FRICTION LOSSES.

The loss of head necessary to overcome internal resistances within the pipe is proportional to the length of the pipe, but is independent of the static pressure in the pipe.

In order to determine the size of pipe and the loss of head necessary to overcome the frictional resistances in the conveyance of a given quantity of water, three estimate diagrams and four tables have been prepared. Examples of typical pipe problems are given. The factors of safety given below should be considered in each problem.

FACTORS OF SAFETY.

As in all conservative design or estimating, factors of safety must be used in order to take care of the divergence, due to unforeseen or abnormal conditions, from a general average.

¹ Pro. 4th An. Conv., W. Can. Irr. Assoc., Ottawa, 1911, p. 76.

² Working Data for Irrigation Engineers, p. 70.

In general a lower factor of safety may be used for a jointed pipe of precast units than for a pipe of monolithic construction. This is true because a given surface may be more closely anticipated before construction.

For pipes of classes 1 and 4 (p. 7) the velocity may be assumed to be within 10 per cent of that computed by the new formula, provided the conditions are favorable.

For pipes of classes 2 and 3 the writer would suggest about the same factors of safety as for wood-stave pipe:

Five per cent when only a rough approximation to the actual needs of the pipe is possible; when water enters the pipe from a settling reservoir or velocities in the pipe are so high that a clean-scoured condition will always be present inside the pipe; and also where conditions of operation are such that no penalties are attached to a slight insufficiency of carrying capacity.

Ten per cent when the above conditions for a very clean pipe are assured, but where penalties are attached to lack of capacity; or where no direct penalties are attached but silted waters and low velocities may permit deposits.

Fifteen per cent where rock ravelings may reduce the interior area of the pipe, or when penalties are attached and silted water is likely to cause excess retardation of flow, or where chemical analyses of the water indicate that accretions may be expected.

The designer may safely assume that the capacity of concrete will not change materially unless the pipe is subject to conditions mentioned on pages 50 and 51.

As a factor for safety to be used in the design of a pipe line, the writer would suggest adding the percentage to the load to be carried rather than a change of coefficients—that is, if 100 second-feet of water is the desired quantity and a factor of 10 per cent is to be used, then design the line for a capacity of 110 second-feet.

ESTIMATE DIAGRAMS AND TABLE; SOLUTIONS FOR TYPICAL PIPE PROBLEMS.

(1) An inverted siphon of class 3 is required to convey 60 second-feet of water a length of 2,800 feet, the velocity at peak load to be about 5 feet per second. Water has settled in a reservoir before entering the canal. The siphon is to contain no abrupt turns or obstructions. No direct penalty has been attached for lack of capacity. Required, diameter of pipe.

Allowing a 5 per cent overload as a factor of safety, the rated capacity will be $60 + 3 = 63$ second-feet. At a velocity of 5 feet per second the area of the water cross section—that is, the inside area of the pipe—must be $\frac{63}{5} = 12.6$ square feet, which is close to the area of a 48-inch pipe. On Plate VII, from the intersection of diameter line 48 and coefficient line 0.345, follow the guide lines to an intersection with velocity line 5. This intersection is on loss-of-head line 1.7 feet per thousand feet of pipe. Thus for a 4-foot pipe 2,800 feet long the friction loss incident to the conveyance of 60 second-feet

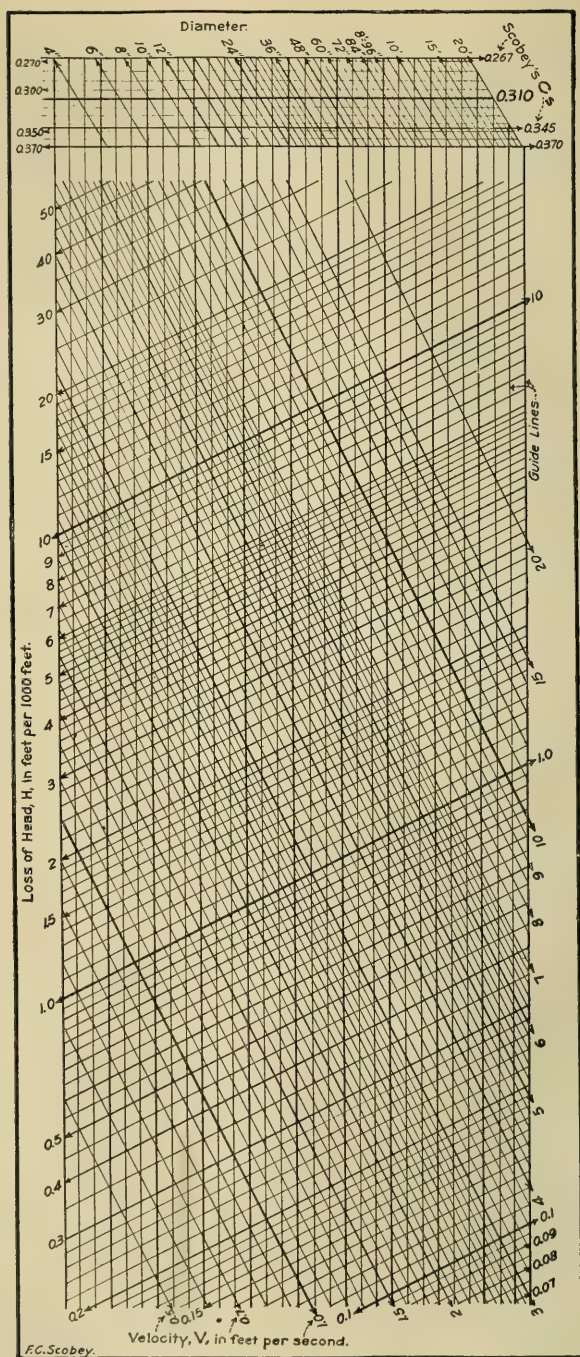


DIAGRAM FOR USE IN THE DESIGN OF CONCRETE PIPE LINES.

From the intersection of the diameter and C_s follow guide lines to the intersection of H and V , or from the intersection of H and V follow guide lines to the intersection of diameter and C_s . No straight edge required. For recommended values of C_s , see page 7.

will be $1.7 \times 2.8 = 4.76$ feet. In addition to this the loss of head necessary to create the velocity of 5 feet per second is $\frac{5^2}{64.4} = 0.4$ foot. Assuming the entry head as one-half the velocity head gives an additional loss of 0.2 foot. Since for most installations there is but little or no recovery of velocity head at the outlet, it may be assumed that the total loss of head will approximate $4.8 + 0.4 + 0.2 = 5.4$ feet. If it is not feasible to sacrifice 5.4 feet a lower maximum velocity may be assumed and the above process repeated, this of course resulting in a larger pipe. If elevation is of little moment, that is, if more grade may be sacrificed, then a higher velocity may be assumed and a smaller pipe used.

The same results may be obtained by interpolating in Table 8.

(2) An orchardist wishes to convey the output of a 5-inch centrifugal pump, rated at 700 gallons per minute, from a standpipe near the well to the high corner of his orchard which is 5 feet higher than the land at the standpipe, and 1,370 feet distant along the line the pipe must follow. The owner wishes to use 12-inch pipe made by the dry-mix process. How high must the standpipe be to deliver the water at the high corner of the orchard with a pressure head of 2 feet still available to insure a free discharge? To provide for an assured capacity of the line, for a slight undersize in the pipe, and a slight overload for the pump, we will figure on 15 per cent more than 700 gallons per minute or $700 + 105 = 805$ gallons per minute. In column 4, Table 6, we find the item 809 as nearest to 805. This is close enough for our computations. Opposite 809 in the columns under a 12-inch pipe we find the velocity V , of such a flow in a 12-inch pipe will be 2.29 feet per second and the friction head for 1,000 feet of pipe, H , will be 2.44 feet. Since our pipe will be 1,370 feet long, this friction head will be $1.37 \times 2.44 = 3.34$ feet. A small amount of fall is also necessary in order to generate the velocity of 2.29 feet per second and to get the water from the standpipe into the flow line. In Table 5, page 52, we find that a velocity of 2.4 feet per second requires a head (fall) of 0.135 foot, according to column 4. Thus the following items enter into the total height of our standpipe:

	Feet.
Difference in elevation of the ground surface.....	5. 00
Reserve pressure head at outlet.....	2. 00
Friction loss in 1,370 feet of 12-inch pipe for 809 G. P. M.....	3. 34
Head to generate velocity and get water into the pipe.....	. 13
Total.....	10. 47

So a standpipe $11\frac{1}{2}$ or 12 feet high, measured from the ground surface, will be sufficient to insure the flow and have some elevation in reserve for "freeboard" and surging.

TABLE 6.—FOR ESTIMATING THE CAPACITY OF MODERN CONCRETE PIPE LINES MADE BY DRY-MIXTURE PROCESS.¹

Based on formula $V = C_d H^{0.5} d^{0.825}$ using 0.310 for the coefficient C_d . For instance, 2 second-feet of water, the equivalent of 80 miner's inches measured under a 6-inch pressure, or of 100 miner's inches measured under a 4-inch pressure, or of 898 gallons per minute, will be conveyed by a 12-inch pipe, with a velocity of 2.55 feet per second with a loss of head (grade) of 3.04 feet for each 1,000 feet of pipe.

Quantity (Q).				Inside diameter, in inches and corresponding area, A, in square feet.											
Sec.-ft.	Miner's inches.		Gallons per minute.	6 A=0.196		8 A=0.349		10 A=0.545		12 A=0.785		14 A=1.069		16 A=1.396	
	A(40)	B(50)		V		V		V		V		V		V	
				Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.		
0.1	4	5	45	0.51	0.28	0.29	0.07								
.2	8	10	90	1.02	1.06	.57	.15								
.3	12	15	135	1.53	2.60	.86	.57								
.4	16	20	180	2.04	4.61	1.14	1.00								
.5	20	25	225	2.55	7.24	1.43	1.58								
.6	24	30	270	3.06	10.40	1.72	2.30	1.10	0.71	0.76	0.27				
.7	28	35	315	3.56	14.00	2.01	3.15	1.28	.96	.89	.37				
.8	32	40	360	4.08	18.40	2.29	4.07	1.47	1.26	1.02	.48	0.75	0.22		
.9	36	45	405	4.58	23.40	2.58	5.16	1.65	1.60	1.14	.61	.84	.27		
1.0	40	50	449	5.10	28.80	2.87	6.38	1.83	1.96	1.27	.75	.94	.34		
1.2	48	60	539	6.11	42.00	3.44	9.15	2.20	2.84	1.53	1.09	1.12	.48	0.86	0.24
1.4	56	70	629	7.13	56.00	4.01	12.50	2.57	3.88	1.78	1.48	1.31	.66	1.00	.33
1.6	64	80	719	8.15	74.00	4.58	16.30	2.93	5.07	2.04	1.95	1.50	.84	1.15	.43
1.8	72	90	809	9.17	93.00	5.16	20.70	3.30	6.46	2.29	2.44	1.68	1.09	1.29	.54
2.0	80	100	898	10.20	105.00	5.73	25.40	3.67	7.95	2.55	3.04	1.87	1.35	1.43	.67
2.2	88	110	988	11.20	140.00	6.30	30.80	4.03	9.50	2.80	3.66	2.06	1.63	1.58	.82
2.4	96	120	1,089	12.20	165.00	6.87	36.50	4.40	11.40	3.06	4.37	2.24	1.93	1.72	.97
2.6	104	130	1,168			7.45	43.00	4.77	13.30	3.31	5.11	2.43	2.28	1.86	1.13
2.8	112	140	1,258			8.02	50.00	5.13	15.50	3.56	5.92	2.62	2.64	2.00	1.30
3.0	120	150	1,348			8.59	57.30	5.50	17.80	3.82	6.81	2.81	3.04	2.15	1.50
3.2	128	160	1,438			9.17	65.30	5.87	20.20	4.07	7.74	2.99	3.44	2.29	1.71
3.4	136	170	1,528			9.74	73.50	6.23	22.80	4.33	8.77	3.18	3.90	2.44	1.94
3.6	144	180	1,618			10.30	82.50	6.60	25.60	4.58	9.82	3.37	4.37	2.59	2.18
3.8	152	190	1,708			10.90	92.20	6.97	28.50	4.84	10.80	3.55	4.86	2.72	2.41
4.0	160	200	1,797					7.33	31.50	5.09	12.20	3.74	5.39	2.86	2.67
4.5	180	225	2,022					8.25	39.70	5.73	15.30	4.21	6.81	3.24	3.64
5.0	200	250	2,247					9.17	49.10	6.37	18.80	4.68	8.41	3.58	4.53
5.5	220	275	2,472					10.10	59.60	7.00	22.80	5.15	10.20	3.94	5.49
6.0	240	300	2,697					11.00	70.70	7.64	27.10	5.61	12.10	4.30	6.54
6.5	260	325	2,922					11.90	82.70	8.27	31.80	6.08	14.20	4.66	7.67
				18 A=1.767		20 A=2.182		22 A=2.640		24 A=3.142		30 A=4.909		36 A=7.068	
				V	H	V	H	V	H	V	H	V	H	V	H
4.5	180	225	2,022	2.55	1.85	2.06	1.05	1.70	0.63	1.43	0.40	0.92	0.13	0.64	0.05
5.0	200	250	2,247	2.83	2.25	2.29	1.29	1.89	.78	1.59	.50	1.02	.16	.71	.06
5.5	220	275	2,472	3.11	2.72	2.52	1.57	2.08	.95	1.75	.60	1.12	.19	.78	.07
6.0	240	300	2,697	3.40	3.24	2.75	1.86	2.27	1.13	1.91	.71	1.22	.22	.85	.09
6.5	260	325	2,922	3.68	3.80	2.98	2.18	2.46	1.32	2.07	.84	1.32	.26	.92	.10
7.0	280	350	3,146	3.96	4.40	3.21	2.54	2.65	1.57	2.23	.97	1.42	.30	.99	.12
7.5	300	375	3,371	4.24	5.05	3.44	2.92	2.84	1.77	2.39	1.12	1.53	.35	1.06	.13
8.0	320	400	3,596	4.53	5.77	3.64	3.32	3.03	2.01	2.55	1.28	1.63	.39	1.13	.15
8.5	340	425	3,821	4.81	6.50	3.90	3.74	3.22	2.26	2.71	1.44	1.73	.45	1.20	.17
9.0	360	450	4,046	5.10	7.30	4.12	4.18	3.41	2.54	2.86	1.50	1.83	.50	1.27	.19
9.5	380	475	4,271	5.38	8.16	4.35	4.66	3.60	2.84	3.02	1.79	1.94	.56	1.34	.21
10.0	400	500	4,496	5.66	8.98	4.58	5.17	3.79	3.15	3.18	1.98	2.04	.62	1.41	.24
11.0	440	550	4,948	6.22	10.50	5.04	6.26	4.17	3.80	3.50	2.41	2.24	.74	1.56	.29
12.0	480	600	5,398	6.79	12.90	5.50	7.43	4.55	4.53	3.82	2.86	2.45	.88	1.70	.34
13.0	520	650	5,847	7.36	15.20	5.96	8.76	4.92	5.29	4.14	3.37	2.65	1.04	1.84	.40
14.0	560	700	6,297	7.92	17.70	6.42	10.20	5.30	6.14	4.46	3.90	2.85	1.20	1.98	.46
15.0	600	750	6,747	8.49	20.30	6.87	11.70	5.60	6.85	4.77	4.46	3.06	1.39	2.12	.53
16.0	640	800	7,197	9.06	23.00	7.33	13.20	6.06	8.02	5.09	5.08	3.26	1.57	2.26	.60
17.0	680	850	7,647	9.62	26.00	7.79	14.90	6.44	9.05	5.42	5.75	3.46	1.77	2.40	.68
18.0	720	900	8,096	10.20	29.30	8.25	16.80	6.82	10.20	5.73	6.45	3.67	2.00	2.55	.77
20.0	800	1,000	8,996	11.30	35.90	9.17	20.70	7.58	12.60	6.37	7.94	4.07	2.46	2.83	.94
22.0	880	1,100	9,896	12.40	43.30	10.10	25.10	8.33	15.10	7.00	9.58	4.48	2.98	3.11	1.14
24.0	960	1,200	10,795	13.60	51.90	11.00	28.80	9.09	18.10	7.64	11.40	4.89	3.55	3.40	1.37
26.0	1,040	1,300	11,695	14.70	60.80	11.90	34.90	9.85	21.30	8.27	13.40	5.30	4.10	3.68	1.60
28.0	1,120	1,400	12,594	15.80	70.10	12.80	40.40	10.60	24.60	8.91	15.60	5.70	4.82	3.96	1.85
30.0	1,200	1,500	13,492			13.70	46.20	11.40	28.40	9.55	17.90	6.11	5.59	4.24	2.12
32.0	1,280	1,600	14,390			14.70	53.30	12.10	32.00	10.20	20.40	6.52	6.30	4.53	2.43

¹ This is the table that should be used in the design of pipe lines made from units 2 to 3 feet long, as ordinarily made by hand in the pipe yards of the Pacific Coast States.

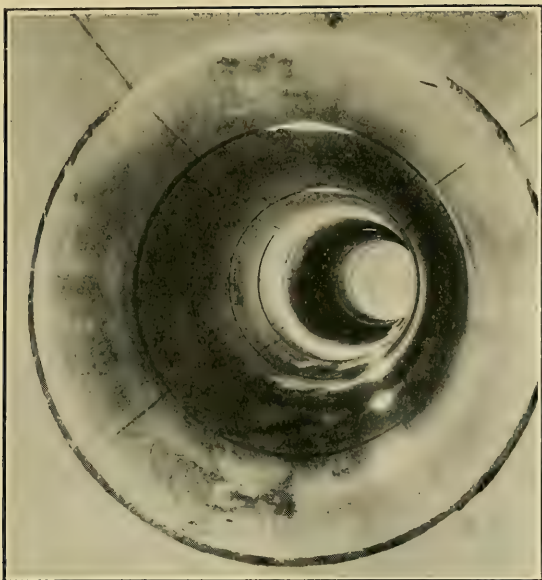


FIG. 1.—FLOW LINE ON VICTORIA AQUEDUCT.
Interior photographed before grouting joints. Spots of sunlight
come through "soup holes" in top of pipe line.

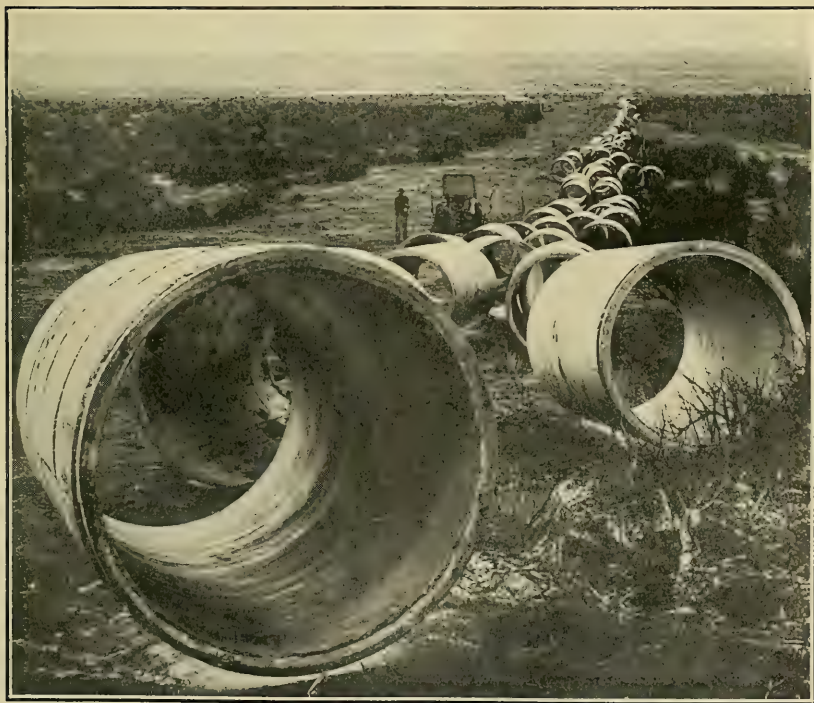


FIG. 2.—R₁ LINE, UMATILLA PROJECT, U. S. RECLAMATION SERVICE, OREGON.
(PIPES NOS. 32 AND 33.)

Inlet at end of clearing in distance. This line under 110 feet of pressure head.



TABLE 7.—FOR ESTIMATING THE CAPACITY OF MODERN "WET-MIX" JOINTED AND WELL-MADE MONOLITHIC CONCRETE PIPE LINES.

Based on formula $V = C_s 170.5 d^{0.625}$ using 0.345 for the coefficient C_s . For instance, 3 second-feet of water, the equivalent of 120 miner's inches of type A or 150 inches of type B, will be conveyed by a 16-inch pipe at a velocity of 2.15 feet per second with a loss of head (grade) of 1.22 feet per thousand feet of pipe.

Quantity (Q).			Inside diameter in inches and corresponding area, A, in square feet.											
			6 A=0.1963		8 A=0.3491		10 A=0.5454		12 A=0.7854		14 A=1.069		16 A=1.396	
			V	H	V	H	V	H	V	H	V	H	V	H
			Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
0.1	4	5	0.51	0.23	0.29	0.05								
.2	8	10	1.02	.93	.57	.20								
.3	12	15	1.53	2.09	.86	.46								
.4	16	20	2.04	3.72	1.14	.81	0.73	0.25						
.5	20	25	2.55	5.82	1.43	1.28	.92	.40						
.6	24	30	3.06	8.38	1.72	1.85	1.10	.57	0.76	0.22				
.7	28	35	3.56	11.30	2.01	2.52	1.28	.77	.89	.30				
.8	32	40	4.08	14.90	2.29	3.28	1.47	1.02	1.02	.39	0.75	0.18		
.9	36	45	4.58	18.80	2.58	4.16	1.65	1.28	1.14	.49	.84	.22		
1.0	40	50	5.09	23.20	2.87	5.14	1.83	1.58	1.27	.61	.94	.27	0.72	0.14
1.2	48	60	6.11	33.40	3.44	7.39	2.20	2.29	1.53	.88	1.12	.39	.86	.19
1.4	56	70	7.13	45.50	4.01	10.00	2.57	3.12	1.78	1.19	1.31	.53	1.00	.26
1.6	64	80	8.15	59.40	4.58	13.10	2.93	4.06	2.04	1.56	1.50	.70	1.15	.35
1.8	72	90	9.17	75.20	5.16	16.60	3.30	5.14	2.29	1.97	1.68	.88	1.29	.44
2.0	80	100	10.20	93.00	5.73	20.50	3.67	6.36	2.55	2.46	1.87	1.09	1.43	.54
2.2	88	110	11.20	112.00	6.30	24.80	4.03	7.67	2.80	2.95	2.06	1.32	1.58	.66
2.4	96	120	12.20	133.00	6.87	29.50	4.40	9.14	3.06	3.52	2.24	1.56	1.72	.78
2.6	104	130	13.20	156.00	7.45	34.70	4.77	10.80	3.31	4.12	2.43	1.83	1.86	.91
2.8	112	140	14.30	182.00	8.02	40.20	5.13	12.40	3.56	4.76	2.62	2.13	2.00	1.05
3.0	120	150	15.30	209.00	8.59	46.10	5.50	14.30	3.82	5.49	2.81	2.45	2.15	1.22
3.2	128	160			9.17	52.50	5.87	16.30	4.07	6.23	2.99	2.77	2.29	1.37
3.4	136	170			9.74	59.30	6.23	18.30	4.33	7.06	3.18	3.14	2.44	1.56
3.6	144	180			10.30	66.30	6.60	20.60	4.58	7.89	3.37	3.52	2.59	1.76
3.8	152	190			10.90	74.20	6.97	23.00	4.84	8.81	3.55	3.91	2.72	1.94
4.0	160	200			11.50	82.60	7.33	25.40	5.09	9.75	3.74	4.34	2.86	2.15
			18 A=1.767		20 A=2.182		22 A=2.640		24 A=3.142		30 A=4.909		36 A=7.068	
			V	H	V	H	V	H	V	H	V	H	V	H
2.0	86	100	1.13	0.29	0.92	0.17	0.76	0.10	0.64	0.06				
2.5	100	125	1.42	.46	1.15	.26	.95	.16	.80	.10	0.51	0.03		
3.0	120	150	1.70	.65	1.37	.37	1.14	.23	.95	.14	.61	.04		
3.5	140	175	1.98	.89	1.60	.51	1.33	.31	1.11	.20	.71	.06	0.50	0.02
4.0	160	200	2.23	1.13	1.83	.66	1.52	.41	1.27	.26	.81	.08	.57	.03
4.5	180	225	2.55	1.47	2.06	.84	1.70	.51	1.43	.32	.92	.10	.64	.04
5.0	200	250	2.83	1.81	2.29	1.04	1.89	.63	1.59	.40	1.02	.12	.71	.05
5.5	220	275	3.11	2.19	2.52	1.26	2.08	.76	1.75	.48	1.12	.15	.78	.06
6.0	240	300	3.40	2.62	2.75	1.50	2.27	.91	1.91	.58	1.22	.19	.85	.07
6.5	260	325	3.68	3.07	2.98	1.76	2.46	1.07	2.07	.68	1.32	.21	.92	.08
7.0	280	350	3.96	3.55	3.21	2.05	2.65	1.24	2.23	.79	1.42	.24	.99	.09
7.5	300	375	4.24	4.07	3.44	2.35	2.84	1.42	2.39	.90	1.53	.28	1.06	.11
8.0	320	400	4.53	4.65	3.67	2.68	3.03	1.62	2.55	1.03	1.63	.32	1.13	.12
8.5	340	425	4.81	5.24	3.90	3.02	3.22	1.83	2.71	1.17	1.73	.36	1.20	.14
9.0	360	450	5.10	5.90	4.12	3.37	3.41	2.05	2.86	1.29	1.83	.40	1.27	.15
9.5	380	475	5.38	6.56	4.35	3.76	3.60	2.29	3.02	1.44	1.94	.45	1.34	.17
10	400	500	5.66	7.26	4.58	4.17	3.79	2.53	3.18	1.60	2.04	.50	1.41	.19
11	440	550	6.22	8.77	5.04	5.04	4.17	3.07	3.50	1.94	2.24	.60	1.56	.23
12	480	600	6.79	10.40	5.50	6.01	4.55	3.65	3.82	2.31	2.44	.71	1.70	.28
13	520	650	7.36	12.30	5.96	7.06	4.92	4.27	4.14	2.71	2.65	.84	1.84	.32
14	560	700	7.92	14.20	6.42	8.19	5.30	4.95	4.46	3.15	2.85	.97	1.98	.37
15	600	750	8.49	16.30	6.87	9.38	5.60	5.53	4.77	3.60	3.06	1.12	2.12	.43
16	640	800	9.06	18.60	7.33	10.70	6.06	6.48	5.09	4.10	3.26	1.27	2.26	.49
17	680	850	9.62	21.00	7.79	12.00	6.44	7.31	5.41	4.63	3.46	1.43	2.40	.55
18	720	900	10.20	23.60	8.25	13.50	6.82	8.20	5.73	5.19	3.67	1.61	2.55	.62
20	800	1,000	11.30	28.90	9.17	16.70	7.58	10.10	6.37	6.42	4.07	1.98	2.83	.76
22	880	1,100	12.40	34.80	10.10	20.30	8.33	12.20	7.00	7.75	4.48	2.40	3.11	.92
24	960	1,200	13.60	41.90	11.00	24.00	9.09	14.60	7.64	9.23	4.89	2.86	3.40	1.10
26	1,040	1,300	14.70	49.00	11.90	28.10	9.85	17.10	8.28	10.80	5.30	3.36	3.68	1.29
28	1,120	1,400	15.80	56.60	12.80	32.60	10.60	19.80	8.91	12.60	5.70	3.89	3.96	1.49
30	1,200	1,500	17.00	65.50	13.70	37.30	11.40	22.90	9.55	14.40	6.11	4.47	4.24	1.71
32	1,280	1,600	18.10	74.20	14.70	42.90	12.10	25.80	10.20	16.50	6.52	5.09	4.53	1.97
34	1,360	1,700	19.20	83.50	15.60	48.30	12.90	29.40	10.80	18.40	6.93	5.74	4.81	2.20
36	1,440	1,800	20.40	94.30	16.50	54.10	13.60	33.10	11.40	20.60	7.33	6.43	5.09	2.47
38	1,520	1,900	21.50	104.60	17.40	60.20	14.40	36.60	12.10	23.10	7.74	7.16	5.38	2.76

¹ Columns headed A(40) and B(50) respectively refer to the number of miner's inches in the equivalent number of second-feet. For instance, 72 miner's inches are the equivalent of 1.8 second-feet in communities where 40 inches equals 1 second-foot.

TABLE 8.—FOR ESTIMATING THE CAPACITY OF WELL-MADE CONCRETE PIPE LINES OR PRESSURE TUNNELS.

Based on formula $V=C_sH^{0.54}d^{0.625}$ using 0.345 for the coefficient C_s .

For instance, 100 second-feet of water, the equivalent of 64.6 million United States gallons per day, will be conveyed in a 48-inch pipe at a velocity of 7.96 feet per second with a loss of head (grade) of 4.22 feet per thousand feet of pipe.

Inside diameter in inches and corresponding area, A, in square feet.																Quantity, millions per day.
Quantity (Q). Sec.- ft.	38 A=7.876		40 A=8.727		42 A=9.621		44 A=10.56		46 A=11.54		48 A=12.57		54 A=15.90			
	V	H	V	H	V	H	V	H	V	H	V	H	V	H		
20	2.54	0.57	2.29	0.44	2.08	0.34	1.89	0.26	1.73	0.21	1.59	0.17	1.26	0.09	12,926	
25	3.17	.89	2.86	.68	2.60	.53	2.37	.42	2.17	.33	1.99	.26	1.57	.14	16,157	
30	3.81	1.29	3.44	.99	3.12	.76	2.85	.60	2.60	.47	2.39	.38	1.89	.21	19,389	
35	4.44	1.76	4.01	1.36	3.64	1.04	3.31	.81	3.03	.64	2.78	.52	2.20	.28	22,621	
40	5.08	2.30	4.58	1.75	4.16	1.36	3.79	1.06	3.47	.84	3.18	.67	2.52	.35	25,853	
45	5.71	2.90	5.16	2.22	4.68	1.72	4.25	1.35	3.90	1.07	3.58	.85	2.83	.46	29,084	
50	6.35	3.59	5.57	2.59	5.20	2.13	4.74	1.67	4.33	1.32	3.98	1.05	3.14	.57	32,316	
55	6.98	4.34	6.30	3.32	5.72	2.57	5.21	2.01	4.77	1.60	4.38	1.28	3.46	.59	35,547	
60	7.62	5.17	6.88	3.95	6.24	3.06	5.68	2.39	5.20	1.90	4.77	1.51	3.77	.82	38,779	
65	8.25	6.06	7.45	4.64	6.76	3.59	6.16	2.82	5.63	2.23	5.17	1.78	4.09	.95	42,010	
70	8.89	7.04	8.02	5.37	7.28	4.17	6.63	3.26	6.07	2.59	5.57	2.06	4.40	1.11	45,242	
75	9.52	8.07	8.59	6.16	7.80	4.78	7.10	3.74	6.50	2.96	5.97	2.37	4.72	1.28	48,474	
80	10.20	9.27	9.17	7.02	8.32	5.44	7.58	4.26	6.93	3.37	6.36	2.69	5.03	1.45	51,705	
85	10.80	10.40	9.74	7.92	8.84	6.14	8.05	4.81	7.37	3.82	6.76	3.04	5.35	1.64	54,937	
90	11.40	11.60	10.30	8.86	9.36	6.88	8.52	5.39	7.80	4.27	7.16	3.41	5.66	1.84	58,168	
100	12.70	14.40	11.50	11.00	10.40	8.50	9.47	6.66	8.67	5.32	7.96	4.22	6.29	2.27	64,631	
110	14.00	17.40	12.60	13.20	11.40	10.20	10.40	8.02	9.53	6.38	8.75	5.09	6.92	2.75	71,096	
120	15.20	20.60	13.80	15.90	12.50	12.30	11.40	9.65	10.40	7.59	9.55	6.07	7.55	3.27	77,558	
130	16.50	24.20	14.90	18.50	13.50	14.30	12.30	11.20	11.30	8.96	10.30	7.12	8.18	3.84	84,021	
140	17.80	28.20	16.00	21.40	14.60	16.80	13.30	13.10	12.10	10.30	11.10	8.19	8.80	4.44	90,484	
150	19.00	32.10	17.20	24.70	15.60	19.10	14.20	15.00	13.00	11.90	11.90	9.42	9.43	5.10	96,947	
160	20.30	36.70	18.30	28.00	16.60	21.60	15.20	17.10	13.90	13.60	12.70	10.70	10.10	5.85	103,410	
170	21.60	41.50	19.50	31.80	17.70	24.60	16.10	19.20	14.70	15.20	13.50	12.10	10.70	6.57	109,870	
180	22.80	46.30	20.60	35.40	18.70	27.50	17.00	21.40	15.60	17.10	14.30	13.30	11.30	7.33	116,340	
190	24.10	51.70	21.80	39.70	19.80	30.80	18.00	24.00	16.50	19.10	15.10	15.20	12.00	8.26	122,800	
60 A=19.64		66 A=23.76		72 A=28.27		78 A=33.18		84 A=38.48		90 A=44.18		96 A=50.26				
50	2.55	0.33	2.10	0.20	1.77	0.13	1.51	0.08	1.30	0.06	1.13	0.04	0.99	0.03	32,316	
55	2.80	.39	2.31	.24	1.94	.15	1.66	.10	1.43	.07	1.24	.05	1.09	.03	35,547	
60	3.06	.47	2.53	.28	2.12	.18	1.81	.12	1.56	.08	1.36	.06	1.19	.04	38,779	
65	3.31	.55	2.74	.33	2.30	.21	1.96	.14	1.69	.09	1.47	.07	1.29	.05	42,070	
70	3.56	.64	2.95	.39	2.48	.25	2.11	.16	1.82	.10	1.58	.08	1.39	.05	45,242	
75	3.82	.73	3.16	.45	2.65	.28	2.26	.18	1.95	.12	1.70	.09	1.49	.06	48,474	
80	4.07	.83	3.37	.51	2.83	.32	2.41	.21	2.08	.14	1.81	.10	1.59	.07	51,705	
85	4.33	.94	3.58	.57	3.01	.36	2.56	.24	2.21	.16	1.92	.11	1.69	.08	54,937	
90	4.58	1.06	3.79	.64	3.18	.40	2.71	.27	2.34	.18	2.04	.13	1.79	.09	58,168	
95	4.84	1.19	4.00	.71	3.36	.45	2.83	.30	2.47	.20	2.15	.14	1.89	.10	61,400	
100	5.09	1.30	4.21	.79	3.54	.50	3.01	.33	2.60	.22	2.26	.15	1.99	.11	64,631	
110	5.60	1.58	4.63	.96	3.89	.61	3.32	.40	2.86	.27	2.49	.19	2.19	.13	71,095	
120	6.11	1.88	5.05	1.14	4.25	.72	3.62	.47	3.12	.32	2.72	.22	2.39	.16	77,558	
130	6.62	2.20	5.47	1.34	4.60	.85	3.92	.56	3.38	.38	2.94	.26	2.59	.19	84,021	
140	7.13	2.56	5.89	1.55	4.95	.98	4.22	.64	3.64	.44	3.17	.30	2.79	.22	90,484	
150	7.64	2.94	6.31	1.78	5.31	1.13	4.52	.74	3.90	.50	3.39	.35	2.98	.25	96,947	
160	8.15	3.34	6.73	2.02	5.66	1.28	4.82	.84	4.16	.57	3.62	.40	3.18	.28	103,410	
170	8.66	3.78	7.16	2.29	6.01	1.45	5.12	.95	4.42	.64	3.85	.45	3.38	.32	109,870	
180	9.17	4.23	7.58	2.56	6.37	1.62	5.43	1.07	4.68	.72	4.07	.50	3.58	.36	116,340	
190	9.67	4.71	8.00	2.86	6.72	1.81	5.73	1.19	4.94	.81	4.30	.56	3.78	.40	122,800	
200	10.20	5.23	8.42	3.16	7.08	2.01	6.03	1.32	5.20	.89	4.53	.62	3.98	.44	129,260	
220	11.20	6.32	9.26	3.83	7.78	2.42	6.63	1.59	5.72	1.08	4.93	.75	4.38	.54	142,190	
240	12.20	7.49	10.10	4.55	8.49	2.89	7.23	1.89	6.24	1.29	5.43	.89	4.78	.64	155,120	
260	13.20	8.77	10.90	5.30	9.20	3.39	7.84	2.23	6.76	1.51	5.88	1.05	5.17	.75	168,040	
280	14.20	10.20	11.80	6.22	9.90	3.93	8.44	2.58	7.28	1.75	6.34	1.22	5.57	.84	180,970	
300	15.20	11.80	12.60	7.09	10.60	4.50	9.04	2.96	7.80	2.01	6.79	1.40	5.97	.95	193,890	
320	16.30	13.40	13.50	8.13	11.30	5.12	9.64	3.36	8.32	2.29	7.24	1.59	6.37	1.13	206,820	
340	17.30	15.10	14.30	9.13	12.00	5.77	10.30	3.84	8.84	2.58	7.70	1.80	6.77	1.28	219,750	
360	18.30	16.90	15.20	10.30	12.70	6.46	10.90	4.30	9.36	2.89	8.15	2.01	7.16	1.43	232,670	
380	19.30	18.80	16.00	11.40	13.40	7.19	11.50	4.79	9.88	3.22	8.60	2.24	7.56	1.60	245,600	

TABLE 8.—FOR ESTIMATING THE CAPACITY OF WELL-MADE CONCRETE PIPE LINES OR PRESSURE TUNNELS—Continued.

For instance, 400 second-feet of water, the equivalent of 259 million U. S. gallons per day, will be conveyed in a 144-inch (12-foot) pipe at a velocity of 3.54 feet per second with a loss of head (grade) of 0.21 feet per thousand feet of pipe.

Quantity (Q.).	Inside diameter in inches and corresponding area, A, in square feet.														Quantity, millions per day.	
	102 A=56.74		108 A=63.62		114 A=70.88		120 A=78.54		126 A=86.59		132 A=95.03		138 A=103.9			
	V	H	V	H	V	H	V	H	V	H	V	H	V	H		
Sec. ft.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Gals.	
160	2.82	0.21	2.51	0.15	2.26	0.11	2.04	0.09	1.85	0.07	1.68	0.05	1.54	0.04	103	
170	3.00	.23	2.67	.17	2.40	.13	2.17	.10	1.96	.08	1.79	.06	1.64	.05	110	
180	3.17	.26	2.83	.19	2.54	.14	2.29	.11	2.08	.09	1.89	.07	1.73	.05	116	
190	3.35	.29	2.99	.22	2.68	.16	2.42	.12	2.19	.10	2.00	.08	1.83	.06	123	
200	3.53	.32	3.14	.24	2.82	.18	2.55	.14	2.31	.11	2.10	.08	1.92	.07	129	
220	3.88	.39	3.46	.29	3.10	.22	2.80	.17	2.54	.13	2.32	.10	2.12	.08	142	
240	4.23	.46	3.77	.34	3.39	.26	3.06	.20	2.77	.15	2.52	.12	2.31	.09	155	
260	4.58	.54	4.09	.40	3.67	.30	3.31	.23	3.00	.18	2.74	.14	2.50	.11	168	
280	4.94	.63	4.40	.47	3.95	.35	3.56	.27	3.23	.21	2.95	.16	2.70	.13	181	
300	5.29	.72	4.72	.54	4.23	.40	3.82	.31	3.46	.24	3.16	.19	2.89	.15	194	
320	5.64	.82	5.03	.61	4.52	.46	4.07	.35	3.69	.27	3.37	.21	3.08	.17	207	
340	5.99	.93	5.34	.69	4.80	.52	4.33	.40	3.93	.31	3.58	.24	3.27	.19	220	
360	6.35	1.04	5.66	.77	5.08	.58	4.58	.45	4.16	.34	3.79	.27	3.46	.21	233	
380	6.70	1.16	5.97	.86	5.36	.65	4.84	.50	4.39	.38	4.00	.30	3.66	.24	246	
400	7.05	1.29	6.29	.95	5.64	.72	5.09	.55	4.62	.42	4.21	.33	3.85	.26	258	
420	7.40	1.42	6.60	1.05	5.92	.79	5.35	.60	4.85	.47	4.42	.37	4.04	.29	271	
440	7.75	1.56	6.92	1.16	6.21	.87	5.60	.66	5.08	.51	4.63	.40	4.24	.32	284	
460	8.11	1.70	7.23	1.26	6.49	.95	5.86	.73	5.31	.56	4.84	.44	4.43	.35	297	
480	8.46	1.86	7.54	1.37	6.77	1.03	6.11	.79	5.54	.61	5.05	.48	4.62	.38	310	
500	8.81	2.01	7.86	1.49	7.05	1.12	6.37	.86	5.77	.66	5.26	.52	4.81	.41	323	
550	9.69	2.43	8.64	1.80	7.76	1.36	7.00	1.04	6.35	.80	5.79	.63	5.29	.50	355	
600	10.60	2.91	9.43	2.15	8.46	1.61	7.64	1.23	6.93	.96	6.31	.75	5.78	.59	388	
650	11.50	3.36	10.20	2.51	9.16	1.90	8.28	1.45	7.51	1.12	6.84	.88	6.26	.70	420	
700	12.39	3.92	11.00	2.92	9.88	2.20	8.91	1.68	8.08	1.30	7.37	1.02	6.74	.81	452	
750	13.20	4.51	11.80	3.36	10.60	2.53	9.55	1.93	8.66	1.49	7.89	1.17	7.22	.92	485	
800	14.10	5.15	12.60	3.83	11.30	2.88	10.20	2.20	9.24	1.70	8.42	1.33	7.70	1.05	517	
850	15.00	5.83	13.40	4.32	12.00	3.24	10.80	2.47	9.82	1.92	8.94	1.50	8.18	1.19	549	
900	15.90	6.55	14.20	4.87	12.70	3.63	11.50	2.80	10.40	2.15	9.47	1.68	8.66	1.33	582	
950	16.80	7.23	14.90	5.35	13.40	4.04	12.10	3.10	11.00	2.41	10.00	1.88	9.14	1.48	614	
1,000	17.60	8.02	15.70	5.95	14.10	4.48	12.70	3.41	11.50	2.63	10.50	2.07	9.69	1.64	646	
144 A=113.1		156 A=132.7		168 A=153.94		180 A=176.71		192 A=201.1		204 A=227.0		216 A=254.5				
	V	H	V	H	V	H	V	H	V	H	V	H	V	H		
200	1.77	0.05	1.51	0.02	1.30	0.02	1.13	0.02	0.99	0.01	0.88	0.01	0.79	0.01	129	
250	2.21	.08	1.88	.05	1.62	.04	1.41	.03	1.24	.02	1.10	.01	.98	.01	162	
300	2.65	.12	2.26	.08	1.95	.05	1.70	.04	1.49	.03	1.32	.02	1.18	.01	194	
350	3.09	.16	2.64	.11	2.27	.07	1.98	.05	1.74	.04	1.54	.03	1.38	.02	226	
400	3.54	.21	3.01	.14	2.60	.09	2.26	.06	1.99	.05	1.76	.03	1.57	.02	259	
450	3.98	.27	3.39	.17	2.92	.12	2.55	.08	2.24	.06	1.98	.04	1.77	.03	291	
500	4.42	.33	3.77	.21	3.25	.15	2.83	.10	2.49	.07	2.20	.05	1.97	.04	323	
550	4.85	.40	4.15	.26	3.57	.18	3.11	.12	2.74	.09	2.42	.07	2.16	.05	355	
600	5.31	.47	4.52	.31	3.90	.21	3.40	.15	2.98	.10	2.64	.08	2.36	.06	388	
650	5.75	.56	4.90	.37	4.22	.25	3.68	.17	3.23	.12	2.86	.09	2.55	.07	420	
700	6.19	.64	5.28	.42	4.55	.29	3.96	.20	3.48	.14	3.08	.10	2.75	.08	452	
750	6.63	.74	5.65	.48	4.87	.33	4.24	.23	3.73	.16	3.30	.12	2.95	.09	485	
800	7.07	.84	6.03	.55	5.20	.38	4.53	.26	3.98	.19	3.52	.14	3.14	.10	517	
850	7.52	.95	6.41	.63	5.52	.42	4.81	.29	4.23	.21	3.74	.15	3.34	.11	549	
900	7.96	1.07	6.78	.70	5.85	.48	5.09	.33	4.48	.24	3.96	.17	3.54	.12	582	
950	8.40	1.19	7.16	.78	6.17	.53	5.38	.37	4.72	.26	4.18	.19	3.73	.14	614	
1,000	8.84	1.32	7.54	.87	6.50	.59	5.66	.41	4.97	.29	4.41	.21	3.93	.16	646	
1,050	9.28	1.45	7.91	.95	6.82	.65	5.94	.45	5.23	.32	4.63	.23	4.12	.17	678	
1,100	9.73	1.59	8.29	1.05	7.15	.71	6.22	.49	5.47	.35	4.85	.26	4.32	.19	711	
1,150	10.20	1.75	8.67	1.14	7.47	.78	6.51	.56	5.72	.38	5.07	.28	4.52	.21	743	
1,200	10.60	1.89	9.04	1.24	7.80	.85	6.79	.59	5.97	.42	5.29	.30	4.71	.23	776	
1,250	11.10	2.07	9.42	1.35	8.12	.92	7.07	.64	6.22	.45	5.51	.33	4.92	.24	807	
1,300	11.50	2.23	9.80	1.46	8.45	.99	7.36	.69	6.47	.49	5.73	.36	5.11	.26	840	
1,400	12.40	2.59	10.60	1.71	9.09	1.15	7.92	.80	6.96	.57	6.17	.41	5.50	.31	905	
1,500	13.30	2.98	11.30	1.94	9.74	1.32	8.49	.92	7.46	.65	6.61	.48	5.90	.35	969	
1,600	14.20	3.39	12.10	2.23	10.40	1.50	9.05	1.04	7.96	.74	7.05	.54	6.29	.40	1,043	
1,700	15.00	3.79	12.80	2.50	11.00	1.68	9.62	1.18	8.46	.84	7.49	.61	6.68	.45	1,098	
1,800	15.90	4.26	13.60	2.82	11.70	1.90	10.20	1.32	8.95	.94	7.93	.68	7.07	.51	1,163	
1,900	16.80	4.75	14.30	3.15	12.30	2.12	10.80	1.48	9.48	1.05	8.37	.76	7.47	.56	1,228	
2,000	17.70	5.27	15.10	3.48	13.00	2.35	11.30	1.62	9.95	1.16	8.81	.85	7.86	.63	1,292	

TABLE 9.—FOR ESTIMATING THE CAPACITY OF GLAZED CONCRETE PIPE LINES.

Based on formula $V = C_s H^{0.547 D^{0.625}}$ using 0.370 for the coefficient C_s . For instance, 140 second-feet of water, the equivalent of 90.5 million United States gallons per day, will be conveyed by a 54-inch pipe at a velocity of 8.80 feet per second with a loss of head (grade) of 3.86 feet per thousand feet of pipe.

Quantity (Q.).	Inside diameter in inches and corresponding area, A, in square feet.														Quantity, millions per day.	
	16 A=1.396		18 A=1.767		20 A=2.182		22 A=2.640		24 A=3.142		30 A=4.909		36 A=7.063			
	V	H	V	H	V	H	V	H	V	H	V	H	V	H		
Sec.-ft.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Gals.	
2.0	1.43	0.48	1.13	0.25	0.92	0.15	0.76	0.09	0.64	0.05	.....	.....	.....	.....	1.29	
2.5	1.79	.73	1.42	.40	1.15	.23	.95	.14	.80	.09	0.51	0.03	.....	.....	1.62	
3.0	2.15	1.06	1.70	.56	1.37	.32	1.14	.20	.95	.12	.61	.03	.....	.....	1.94	
3.5	2.51	1.44	1.98	.77	1.60	.44	1.33	.27	1.11	.17	.71	.05	0.50	0.02	2.26	
4.0	2.86	1.87	2.23	.98	1.83	.57	1.52	.36	1.27	.23	.81	.07	.57	.03	2.58	
4.5	3.22	2.35	2.55	1.28	2.06	.73	1.70	.44	1.43	.28	.92	.09	.64	.03	2.91	
5.0	3.58	2.92	2.83	1.57	2.29	.90	1.89	.55	1.59	.35	1.02	.10	.71	.04	3.23	
5.5	3.94	3.54	3.11	1.90	2.52	1.10	2.08	.66	1.75	.42	1.12	.13	.78	.05	3.55	
6.0	4.30	4.22	3.40	2.28	2.75	1.30	2.27	.79	1.91	.50	1.22	.16	.85	.06	3.83	
6.5	4.66	4.95	3.68	2.67	2.98	1.53	2.46	.93	2.07	.59	1.32	.18	.92	.07	4.20	
7.0	5.01	5.73	3.96	3.09	3.21	1.78	2.65	1.08	2.23	.69	1.42	.21	.99	.08	4.52	
7.5	5.37	6.58	4.24	3.54	3.44	2.04	2.84	1.23	2.39	.78	1.53	.24	1.06	.10	4.85	
8.0	5.72	7.49	4.53	4.04	3.67	2.33	3.03	1.41	2.55	.90	1.63	.28	1.13	.10	5.17	
8.5	6.09	8.46	4.81	4.56	3.90	2.62	3.22	1.59	2.71	1.02	1.73	.31	1.20	.12	5.49	
9.0	6.45	9.49	5.10	5.13	4.12	2.93	3.41	1.78	2.86	1.12	1.83	.35	1.27	.13	5.82	
9.5	6.80	10.60	5.38	5.70	4.35	3.27	3.60	1.99	3.02	1.25	1.94	.39	1.34	.15	6.14	
10	7.16	11.70	5.66	6.31	4.58	3.62	3.79	2.20	3.18	1.39	2.04	.43	1.41	.16	6.46	
11	7.88	14.20	6.22	7.62	5.04	4.38	4.17	2.67	3.50	1.69	2.24	.52	1.56	.20	7.11	
12	8.60	16.90	6.79	9.04	5.50	5.22	4.55	3.17	3.82	2.01	2.44	.62	1.70	.24	7.76	
13	9.31	19.90	7.36	10.70	5.96	6.14	4.92	3.71	4.14	2.36	2.65	.73	1.84	.28	8.40	
14	10.00	22.90	7.92	12.30	6.42	7.12	5.30	4.30	4.46	2.74	2.85	.84	1.98	.32	9.00	
15	10.70	26.30	8.49	14.20	6.87	8.16	5.60	4.81	4.77	3.13	3.06	.97	2.12	.37	9.69	
16	11.50	30.10	9.06	16.20	7.33	9.30	6.06	5.43	5.09	3.56	3.26	1.10	2.26	.43	10.30	
17	12.20	34.00	9.62	18.20	7.79	10.40	6.44	6.36	5.41	4.02	3.46	1.24	2.40	.48	11.00	
18	12.90	38.00	10.20	20.50	8.25	11.70	6.82	7.13	5.73	4.51	3.67	1.40	2.55	.54	11.60	
20	14.30	46.60	11.30	25.10	9.17	14.50	7.58	8.78	6.39	5.58	4.07	1.72	2.83	.66	12.90	
22	15.80	56.90	12.40	30.10	10.10	17.60	8.33	10.60	7.00	6.74	4.48	2.09	3.11	.80	14.20	
24	17.20	67.50	13.60	36.40	11.00	20.80	9.09	12.80	7.64	8.02	4.89	2.49	3.40	.96	15.50	
26	18.60	78.90	14.70	42.60	11.90	24.40	9.85	14.90	8.27	9.39	5.30	2.92	3.68	1.12	16.80	
28	20.00	91.30	15.80	49.20	12.80	28.30	10.60	17.20	8.91	11.00	5.70	3.38	3.96	1.30	18.10	
30	21.50	105.50	17.00	56.90	13.70	32.40	11.40	20.00	9.55	12.50	6.11	3.89	4.24	1.49	19.40	
32	22.90	114.60	18.10	64.10	14.70	37.30	12.10	22.40	10.20	14.30	6.52	4.42	4.53	1.71	20.70	
34	24.00	135.70	19.20	72.60	15.60	42.00	12.90	25.60	10.80	16.00	6.93	4.99	4.81	1.91	22.00	
36	25.80	151.80	20.40	82.00	16.50	47.00	13.60	28.80	11.40	17.90	7.33	5.59	5.08	2.15	23.30	
38	27.20	168.60	21.50	90.90	17.40	52.00	14.40	31.80	12.10	20.10	7.74	6.22	5.38	2.40	24.50	
	38 A=7.876		40 A=8.727		42 A=9.621		44 A=10.56		46 A=11.54		48 A=12.57		54 A=15.90			
	V	H	V	H	V	H	V	H	V	H	V	H	V	H		
20	2.54	0.50	2.29	0.38	2.08	0.30	1.89	0.23	1.73	0.18	1.59	0.15	1.26	0.08	12.9	
25	3.17	.77	2.86	.59	2.60	.46	2.37	.37	2.17	.29	1.99	.23	1.57	.12	16.2	
30	3.81	1.12	3.44	.86	3.12	.66	2.85	.52	2.60	.41	2.39	.33	1.89	.18	19.3	
35	4.44	1.53	4.01	1.18	3.64	.90	3.31	.70	3.03	.56	2.78	.45	2.20	.24	22.6	
40	5.08	2.00	4.58	1.52	4.16	1.18	3.79	.92	3.47	.73	3.18	.58	2.52	.31	25.9	
45	5.71	2.52	5.16	1.93	4.68	1.50	4.26	1.17	3.90	.93	3.58	.74	2.83	.40	29.1	
50	6.35	3.12	5.57	2.25	5.20	1.85	4.74	1.45	4.33	1.15	3.98	.91	3.14	.50	32.3	
55	6.98	3.77	6.30	2.89	5.72	2.23	5.21	1.75	4.77	1.39	4.38	1.11	3.46	.60	35.5	
60	7.62	4.49	6.88	3.43	6.24	2.66	5.68	2.08	5.20	1.65	4.77	1.31	3.77	.71	38.8	
65	8.25	5.27	7.45	4.03	6.76	3.12	6.16	2.45	5.63	1.94	5.17	1.55	4.09	.83	42.0	
70	8.89	6.12	8.02	4.67	7.28	3.62	6.63	2.83	6.07	2.25	5.57	1.79	4.40	.96	45.2	
75	9.52	7.02	8.59	5.36	7.80	4.16	7.10	3.25	6.50	2.57	5.97	2.06	4.72	1.11	48.5	
80	10.20	8.06	9.17	6.10	8.32	4.73	7.58	3.70	6.93	2.93	6.36	2.34	5.03	1.26	51.7	
85	10.80	9.04	9.74	6.88	8.84	5.34	8.05	4.18	7.37	3.32	6.76	2.64	5.35	1.42	54.9	
90	11.40	10.10	10.30	7.70	9.36	5.98	8.52	4.69	7.80	3.71	7.16	2.96	5.66	1.60	58.2	
100	12.70	12.50	11.50	9.56	10.40	7.39	9.47	5.79	8.67	4.62	7.96	3.67	6.29	1.97	64.6	
110	14.00	15.10	12.60	11.50	11.40	8.87	10.40	6.97	9.53	5.55	8.75	4.42	6.92	2.39	71.1	
120	15.20	17.90	13.80	13.80	12.50	10.70	11.40	8.89	10.40	6.60	9.55	5.22	7.55	2.84	77.6	
130	16.50	21.00	14.90	16.10	13.50	12.40	12.30	9.74	11.30	7.79	10.30	6.19	8.18	3.34	84.0	
140	17.80	24.50	16.00	18.60	14.60	14.60	13.30	11.40	12.10	8.90	11.10	7.12	8.80	3.86	90.5	
150	19.00	27.90	17.20	21.50	15.60	16.60	14.20	13.00	13.00	10.30	11.90	8.19	9.43	4.43	96.9	
160	20.30	31.90	18.30	24.30	16.60	18.80	15.20	14.80	13.90	11.80	12.70	9.30	10.10	5.09	103.0	
170	21.60	36.10	19.50	27.60	17.70	21.40	16.10	16.70	14.70	13.20	13.50	10.50	10.70	5.71	110.0	
180	22.80	40.20	20.60	30.80	18.70	23.90	17.00	18.60	15.60	14.90	14.30	11.80	11.30	6.37	116.0	
190	24.10	44.90	21.80	34.50	19.80	26.80	18.00	20.90	16.50	16.60	15.10	13.20	12.00	7.18	123.0	

TABLE 9.—FOR ESTIMATING THE CAPACITY OF GLAZED CONCRETE PIPE LINES—Continued.

For instance, 400 second-feet of water, the equivalent of 259 million United States gallons per day, will be conveyed by a 120-inch pipe at a velocity of 5.09 feet per second with a loss of head (grade) of 0.48 foot per thousand feet of pipe.

Quantity (Q).	Inside diameter in inches and corresponding area, A, in square feet.																Quantity, millions per day.	
	60 A=19.64		66 A=23.76		72 A=28.27		78 A=33.18		84 A=38.48		90 A=44.18		96 A=50.26					
	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H		
Sec.-ft.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Gals.	
50	2.55	0.29	2.10	0.17	1.77	0.11	1.51	0.07	1.30	0.05	1.13	0.03	0.99	0.03	32.3			
55	2.80	.34	2.31	.21	1.94	.13	1.66	.09	1.43	.06	1.24	.04	1.09	.03	35.5			
60	3.06	.41	2.53	.24	2.12	.16	1.81	.10	1.56	.07	1.36	.05	1.19	.03	38.8			
65	3.31	.48	2.74	.29	2.30	.18	1.96	.12	1.69	.08	1.47	.06	1.29	.04	42.0			
70	3.56	.56	2.95	.34	2.48	.22	2.11	.14	1.82	.09	1.58	.07	1.39	.04	45.2			
75	3.82	.63	3.16	.39	2.65	.24	2.26	.16	1.95	.10	1.70	.08	1.49	.05	48.5			
80	4.07	.72	3.37	.44	2.83	.28	2.41	.18	2.08	.12	1.81	.09	1.59	.06	51.7			
85	4.33	.82	3.58	.50	3.01	.31	2.56	.21	2.21	.14	1.92	.10	1.69	.07	54.9			
90	4.58	.92	3.79	.56	3.18	.35	2.71	.23	2.34	.16	2.04	.11	1.79	.08	58.2			
95	4.84	1.03	4.00	.62	3.36	.39	2.86	.26	2.47	.17	2.15	.12	1.89	.09	61.4			
100	5.09	1.13	4.21	.69	3.54	.43	3.01	.29	2.60	.19	2.26	.13	1.99	.10	64.6			
110	5.60	1.37	4.63	.83	3.89	.53	3.32	.35	2.86	.23	2.49	.16	2.19	.12	71.1			
120	6.11	1.63	5.05	.99	4.25	.62	3.62	.41	3.12	.28	2.72	.19	2.39	.14	77.6			
130	6.62	1.91	5.47	1.16	4.60	.74	3.92	.49	3.38	.33	2.94	.23	2.59	.17	84.0			
140	7.13	2.22	5.89	1.35	4.95	.85	4.22	.56	3.64	.38	3.17	.26	2.79	.19	90.6			
150	7.64	2.56	6.31	1.55	5.31	.98	4.52	.64	3.90	.43	3.39	.30	2.98	.22	96.9			
160	8.15	2.90	6.73	1.76	5.66	1.11	4.82	.73	4.16	.50	3.62	.35	3.18	.24	103.0			
170	8.66	3.29	7.16	1.99	6.01	1.26	5.12	.82	4.42	.56	3.85	.39	3.38	.28	110.0			
180	9.17	3.68	7.58	2.22	6.37	1.41	5.43	.93	4.68	.62	4.07	.43	3.58	.31	116.0			
190	9.67	4.10	8.00	2.49	6.72	1.57	5.73	1.03	4.94	.70	4.30	.49	3.78	.35	123.0			
200	10.20	4.55	8.42	2.75	7.08	1.75	6.03	1.15	5.20	.77	4.53	.54	3.98	.38	129.0			
220	11.20	5.49	9.26	3.33	7.78	2.10	6.63	1.38	5.72	.94	4.98	.65	4.38	.47	142.0			
240	12.20	6.51	10.10	3.96	8.49	2.51	7.23	1.64	6.24	1.12	5.43	.77	4.78	.56	155.0			
260	13.20	7.62	10.90	4.61	9.20	2.95	7.84	1.94	6.76	1.31	5.88	.91	5.17	.65	168.0			
280	14.20	8.87	11.80	5.41	9.90	3.42	8.44	2.24	7.28	1.52	6.34	1.06	5.57	.73	181.0			
300	15.30	10.20	12.60	6.23	10.60	3.91	9.04	2.57	7.80	1.75	6.79	1.22	5.97	.83	194.0			
320	16.30	11.60	13.50	7.07	11.30	4.45	9.64	2.92	8.32	1.99	7.24	1.38	6.37	.98	207.0			
340	17.30	13.10	14.30	7.94	12.00	5.02	10.30	3.34	8.84	2.24	7.70	1.56	6.77	1.11	220.0			
360	18.30	14.70	15.20	8.86	12.70	5.62	10.90	3.74	9.36	2.51	8.15	1.75	7.16	1.24	233.0			
380	19.30	16.30	16.00	9.91	13.40	6.25	11.50	4.16	9.88	2.80	8.60	1.95	7.56	1.39	246.0			
	102 A=56.74		108 A=63.62		114 A=70.88		120 A=78.54		126 A=86.59		132 A=95.03		138 A=103.9					
	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H		
160	2.82	0.18	2.51	0.13	2.26	0.10	2.04	0.08	1.85	0.06	1.68	0.04	1.54	0.03	103			
170	3.00	.20	2.67	.15	2.40	.11	2.17	.09	1.96	.07	1.79	.05	1.64	.04	110			
180	3.17	.23	2.83	.17	2.54	.12	2.29	.10	2.08	.08	1.89	.06	1.73	.04	116			
190	3.35	.25	2.99	.19	2.68	.14	2.42	.11	2.19	.09	2.00	.07	1.83	.05	123			
200	3.53	.28	3.14	.21	2.82	.16	2.55	.12	2.31	.10	2.10	.07	1.92	.06	129			
220	3.88	.34	3.46	.25	3.10	.19	2.80	.15	2.54	.11	2.32	.09	2.12	.07	142			
240	4.23	.40	3.77	.30	3.39	.23	3.06	.17	2.77	.13	2.52	.10	2.31	.08	155			
260	4.58	.47	4.09	.35	3.67	.26	3.31	.20	3.00	.16	2.74	.12	2.50	.10	168			
280	4.94	.55	4.40	.41	3.95	.30	3.56	.23	3.23	.18	2.95	.14	2.70	.11	181			
300	5.29	.62	4.72	.47	4.23	.35	3.82	.27	3.46	.21	3.16	.16	2.89	.13	194			
320	5.64	.71	5.03	.53	4.52	.40	4.07	.30	3.69	.23	3.37	.18	3.08	.15	206			
340	5.99	.81	5.34	.60	4.80	.45	4.33	.35	3.93	.27	3.58	.21	3.27	.16	220			
360	6.35	.90	5.66	.67	5.08	.50	4.58	.39	4.16	.30	3.79	.23	3.46	.18	233			
380	6.70	1.01	5.97	.75	5.36	.56	4.84	.43	4.39	.33	4.00	.26	3.66	.21	246			
400	7.05	1.12	6.29	.82	5.64	.62	5.09	.48	4.62	.36	4.21	.29	3.85	.23	259			
420	7.40	1.23	6.60	.91	5.92	.69	5.35	.52	4.85	.41	4.42	.32	4.04	.25	271			
440	7.75	1.36	6.92	1.01	6.20	.76	5.60	.57	5.08	.44	4.63	.35	4.24	.28	284			
460	8.11	1.48	7.23	1.10	6.49	.82	5.86	.63	5.31	.49	4.84	.38	4.43	.30	297			
480	8.46	1.62	7.54	1.19	6.72	.90	6.11	.69	5.54	.53	5.05	.42	4.62	.33	310			
500	8.81	1.75	7.86	1.30	7.05	.97	6.37	.75	5.77	.57	5.26	.45	4.81	.36	323			
550	9.69	2.11	8.64	1.56	7.76	1.18	7.00	.90	6.35	.70	5.79	.55	5.29	.43	355			
600	10.60	2.53	9.43	1.87	8.46	1.40	7.64	1.07	6.93	.83	6.31	.65	5.78	.51	388			
650	11.50	2.92	10.20	2.18	9.16	1.65	8.28	1.26	7.51	.97	6.84	.76	6.26	.60	420			
700	12.30	3.41	11.00	2.54	9.88	1.91	8.91	1.46	8.08	1.13	7.37	.89	6.74	.70	452			
750	13.20	3.92	11.80	2.92	10.60	2.20	9.55	1.68	8.66	1.30	7.89	1.02	7.22	.80	485			
800	14.10	4.48	12.60	3.30	11.30	2.50	10.20	1.91	9.24	1.48	8.42	1.16	7.71	.91	517			
850	15.00	5.07	13.40	3.76	12.00	2.82	10.90	2.15	9.82	1.67	8.94	1.30	8.18	1.03	549			
900	15.90	5.69	14.20	4.23	12.70	3.16	11.50	2.43	10.40	1.87	9.47	1.46	8.66	1.16	582			
950	16.80	6.28	14.90	4.66	13.40	3.51	12.10	2.70	11.00	2.10	10.00	1.63	9.14	1.29	614			
1,000	17.60	6.97	15.70	5.17	14.10	3.90	12.70	2.96	11.50	3.16	10.50	1.80	9.63	1.43	646			

TABLE 10.—VELOCITIES, IN FEET PER SECOND, AS COMPUTED BY VARIOUS FORMULAS FOR GIVEN SIZES OF PIPE WITH GIVEN FRICTION HEADS.

1	2	Velocities, in feet per second, by formulas.																				20
		Scobey. Coefficient (C_s).				Williams-Hazen. Coefficient (C_w).								Kutter. Coefficient (n).						Moritz. Coefficient (C_m).		
		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Scobey. ¹			
		0.267	0.310	0.345	0.370	90	100	110	120	130	140	0.014	0.013	0.012	0.0115	0.011	1.24	1.31				
Diam- eter (d).	Fric- tion head (H).																					
<i>Ins.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>			
6	2.0	1.16	1.35	-----	-----	1.11	1.24	1.36	1.48	1.61	-----	1.01	1.09	1.24	-----	-----	1.45	1.53	1.52			
6	5.0	1.83	2.10	-----	-----	1.84	2.04	2.25	2.45	2.65	-----	1.61	1.73	1.98	-----	-----	2.37	2.50	2.52			
6	9.0	2.46	2.85	-----	-----	2.52	2.80	3.08	3.36	3.64	-----	2.15	2.33	2.68	-----	-----	3.28	3.47	3.50			
12	1.0	1.26	1.47	1.63	1.75	1.19	1.32	1.45	1.58	1.72	1.85	1.22	1.35	1.48	1.56	1.65	1.58	1.67	1.62			
12	5.0	2.82	3.28	3.65	3.91	2.84	3.15	3.47	3.78	4.10	4.40	2.74	3.02	3.36	3.54	3.75	3.86	4.08	3.96			
12	9.0	3.79	4.39	4.89	5.25	3.89	4.33	4.76	5.19	5.62	6.06	3.70	4.05	4.50	4.72	5.00	5.36	5.66	5.48			
36	0.2	1.12	1.30	1.45	1.55	0.99	1.11	1.22	1.33	1.44	1.55	1.19	1.34	1.48	1.53	1.66	1.39	1.47	1.35			
36	1.0	2.51	2.91	3.24	3.47	2.38	2.64	2.91	3.16	3.43	3.69	2.76	3.01	3.31	3.49	3.73	3.40	3.59	3.31			
36	5.0	5.61	6.51	7.24	7.77	5.66	6.30	6.92	7.55	8.18	8.81	6.20	6.74	7.48	7.85	8.30	8.33	8.80	8.08			
72	0.2	-----	-----	2.21	2.40	1.54	1.71	1.88	2.06	2.23	2.40	1.96	2.12	2.31	2.43	2.59	2.26	2.39	2.12			
72	1.0	-----	-----	5.00	5.36	3.68	4.08	4.49	4.89	5.31	5.71	4.46	4.83	5.27	5.51	5.79	5.52	5.84	5.19			
72	2.0	-----	-----	7.07	7.58	5.35	5.94	6.54	7.14	7.73	8.32	6.31	6.86	7.47	7.80	8.20	8.14	8.59	7.63			
96	0.2	-----	-----	2.67	2.87	1.85	2.06	2.26	2.46	2.67	2.88	2.39	2.58	2.81	2.94	3.07	2.77	2.93	2.56			
96	0.6	-----	-----	4.62	4.91	3.34	3.72	4.08	4.46	4.83	5.21	4.18	4.51	4.90	5.11	5.37	5.20	5.39	4.70			
96	1.0	-----	-----	5.98	6.41	4.41	4.90	5.38	5.78	6.37	6.86	5.40	5.84	6.34	6.61	6.95	6.77	7.15	6.26			
120	0.2	-----	-----	3.08	3.30	2.13	2.37	2.60	2.84	3.08	3.31	2.77	3.00	3.24	3.38	3.57	3.24	3.42	2.96			
120	0.6	-----	-----	5.37	5.71	3.85	4.28	4.71	5.14	5.57	5.98	5.82	5.20	5.65	5.89	6.18	5.96	6.30	5.45			
120	1.0	-----	-----	6.88	7.37	5.08	5.64	6.20	6.76	7.32	7.90	6.23	6.73	7.30	7.62	7.98	7.92	8.36	7.24			
144	0.2	-----	-----	3.45	3.70	2.39	2.65	2.92	3.18	3.45	3.71	3.13	3.37	3.65	3.80	3.99	3.65	3.85	3.33			
144	0.6	-----	-----	5.97	6.40	4.32	4.80	5.27	5.75	6.23	6.70	5.43	5.84	6.34	6.61	6.92	6.76	7.13	6.14			
144	1.0	-----	-----	7.71	8.26	5.69	6.32	6.96	7.58	8.21	8.85	7.00	7.55	8.18	8.53	8.93	8.95	9.45	8.15			

¹ Based on formula for velocity in average wood-stave pipe; $V=1.62 D^{-.65} H^{-.55}$. (See Dept. Bul. 376, p. 7.)

COMPARISON OF THE VARIOUS FORMULAS.

For the reason that there are at least four distinct classes of concrete pipes, considered from a capacity standpoint, it was not feasible to make a percentage or graphical comparison between the recommended formula, with varying coefficients and the other formulas mentioned on pages 5 to 8. Of these other formulas, some consider the influences of varying surfaces by means of coefficients, while others are inelastic and were offered for "clean pipes," regardless of materials.

The point that must be kept continually in mind is that concrete pipes offer a greater range of interior surfaces, due to their initial construction, than pipes of any other material, considered by itself, or pipes of all other materials, considered together. These concrete surfaces are almost unbelievably different, aside from all fouling by growths, slimes, or erosion.

In the following discussion classes 1, 2, 3, and 4 will be considered as was described on page 8, in connection with the new formula, the latter being considered as the base from which a comparison is made.

The values of the various coefficients are for favorable conditions, and factors of safety, as listed on page 54 should be used in design.

For a comparison of velocities, as computed from various formulas, for various sizes of pipe and for varying friction heads, the reader is referred to table 10, page 62.

Again taking up the various formulas mentioned on pages 5 to 7; the Chezy formula (4, p. 6), will not be considered directly, but in its modified form, known as Kutter's formula (5, p. 6).

THE KUTTER FORMULA.

In discussing the Moritz experiments with reference to the value of n in Kutter's formula, Hering states¹ that he "recognized as well as did Mr. Kutter himself, almost at the outset, that n was not to be considered a precise and unvarying constant, although it was more nearly so than any other constant before proposed."

The fact that n does vary has been understood by hydraulicians specializing in work involving the Kutter formula; but notwithstanding this the tables and diagrams which have been accepted as standard have assigned values of n to certain degrees of roughness without reference to other conditions. The usual understanding regarding variation occurring in the value for n has been that n is less in large channels than in small ones.

In the case of pipes an opposite effect is noted; that is, the value of n becomes greater as the value of R (which is directly proportional to the diameter) becomes greater. The variations in the proper value of n to assume in the design of pipe become so complicated that the Kutter formula had better be abandoned in favor of the exponential type of formula. This would leave the Kutter formula for its original intended purpose, that of design of open channels, for which it is eminently fitted.²

However, for those who wish to use the Kutter formula, the following suggestions are made. Note that the value of n changes with diameter. If velocities are to exceed 8 feet per second, the next lower value of n may be safely used. The values of n given presuppose the use of some factor of safety about as given on page 54:

- Class 1. $n=0.013$ for pipes up to 10 inches in diameter.
 $n=0.014$ for pipes from 12 to 24 inches in diameter.
 $n=0.015$ for pipes from 26 to 42 inches in diameter.
- Class 2. $n=0.013$ for pipes up to 36 inches in diameter.
- Class 3. $n=0.012$ for pipes up to 24 inches in diameter.
 $n=0.013$ for pipes more than 24 inches in diameter.
- Class 4. $n=0.011$ for pipes from 12 to 24 inches in diameter.
 $n=0.0115$ for pipes from 26 to 48 inches in diameter.
 $n=0.012$ for pipes more than 50 inches in diameter

In order to solve problems involving the Kutter formula, Plate XII is given. As being applicable to open channels rather than closed

¹ Trans. Amer. Soc. Civ. Engin., 74 (1911), p. 459.

² The Flow of Water in Irrigation Channels, by Fred. C. Scobey, U. S. Dept. Agr. Bul. 194, p. 60.

pipes, the hydraulic radius is given instead of the diameter, but the diagram may be used directly for pipes, since $R = \frac{D}{4}$, that is, the hydraulic radius of a 6-foot pipe is $\frac{6}{4} = 1.5$ feet.

THE WEISBACH FORMULA (6, P. 6).

For those who wish to use this rather popular textbook formula, the following values of f are suggested, presupposing the use of some factor of safety about as listed on page 54.

- Class 1. $f=0.040$ for pipes up to 24 inches in diameter.
 $f=0.030$ for pipes from 26 to 42 inches in diameter.
- Class 2. $f=0.030$ for pipes up to 18 inches in diameter.
 $f=0.025$ for pipes from 20 inches to 36 inches in diameter.
- Class 3. $f=0.020$ for pipes up to 48 inches in diameter.
 $f=0.015$ for pipes more than 48 inches in diameter.
- Class 4. $f=0.015$ for pipes up to 48 inches in diameter.
 $f=0.012$ for pipes more than 48 inches in diameter.

THE WILLIAMS-HAZEN FORMULA (7, p. 6).

This formula, being made elastic by varying coefficients, applies very closely within the usual range of velocities. The following values of C_w are suggested, presupposing the use of factors of safety as listed on page 54. For velocities exceeding 5 feet per second use a coefficient of C_w about 10 lower.

- Class 1. $C_w=90$.
- Class 2. $C_w=110$.
- Class 3. $C_w=120$.
- Class 4. $C_w=140$.

THE MORITZ FORMULA (9, p. 7).

The results of the experiments show that the lines of differentiation between classes of concrete surface may be slightly at variance with those suggested by Moritz (see p. 7). A pipe constructed in place with steel forms may have very appreciable shoulders at the ends of the "set-ups," while a jointed pipe may be very smooth at the joints as well as through each unit.

As shown on Plate VI and on page 47, the exponent of D , the velocity is more nearly 2 than 1.80; therefore the application of the Moritz formula changes with the velocities rather than with the diameters, since his exponent of d or D , the diameter, practically agrees with that of the writer.

Using the classification as listed on page 7 and presupposing the use of factors of safety about as given on page 54, the coefficients in the Moritz formula are about as follows:

- Class 1. $C_m=0.90$ for velocities up to 3 feet per second.
- Class 2. $C_m=1.15$ for velocities up to 3 feet per second.
1.10 for velocities from 3 to 6 feet per second.
- Class 3. $C_m=1.25$ for velocities less than 2 feet per second.
1.20 for velocities between 2 and 4 feet per second.
1.15 for velocities between 4 and 6 feet per second.
1.10 for velocities between 6 and 8 feet per second.
- Class 4. $C_m=1.35$ for velocities less than 2 feet per second.
1.30 for velocities between 2 and 4 feet per second.
1.20 for velocities between 4 and 6 feet per second.

CAPACITY OF CONCRETE PIPE COMPARED WITH THAT OF WOOD-STAVE, CAST-IRON, AND RIVETED STEEL PIPE.

Since there are so many classes of concrete pipe, a table showing percentage comparisons between the capacity of each class of pipe with the capacity of pipes of each of the other materials at various ages would be extensive and confusing, so Table 10 may be used. This table gives velocities; capacity for a given size pipe is proportional to velocity.

In a study of this table, the concrete pipe under consideration will classify under columns 3, 4, 5, or 6, according to the class descriptions given on page 7. Average wood-stave pipe comes under column 20. Cast iron and riveted steel come under columns 8, 9, or 11, according to age of the pipe. The coefficients in their formula recommended by Hazen and Williams for new cast iron, new riveted steel, 10-year-old cast iron, 20-year-old cast iron, and 10-year-old riveted steel are, respectively, 130, 110, 110, 100, and 100.

PART 2. FLOW OF WATER IN GRADE LINE PIPES.

PIPES PARTIALLY FILLED.

All available data bearing upon the capacity of concrete pipes and other covered conduits flowing partially full are summarized in Table 11, page 68.

The coefficient of retardation has been computed for five of the best known formulas in use in this country for the design of open channels. The formulas considered are the Chezy formula (No. 3, p. 6); the Kutter formula (No. 5, p. 6); the Williams-Hazen formula (No. 7, p. 6); the Manning formula,¹

$$V = \frac{1.486}{n} R^{0.67} S^{0.5} \quad (20)$$

in which n has approximately the same values as in the Kutter formula; the Bazin (1897) formula,

$$V = \frac{157.6}{1 + \frac{m}{\sqrt{R}}} R^{0.5} S^{0.5} \quad (21)$$

For the smoothest cement channels a value of 0.109 for m is suggested in a table found in many textbooks, probably suggested by the first experiment on the Sudbury Conduit. See page 69. A glance at column 17, Table 11, shows that the value of m changes very rapidly with comparatively small changes of surface and of the various hydraulic elements. The writer believes that the formulas of Kutter, Manning, and Williams-Hazen can be applied with much more assuredness than that of Bazin, if a constant retardation factor is to be used for a given surface.

As the pipes and conduits are not under pressure, but for the most part are laid on an even gradient, where the hydraulic grade line lies parallel to and just under the intrados, it is perfectly proper to regard the pipe as an open channel.

In the opinion of the writer the Kutter formula appears to apply, and as this formula is undoubtedly the one most used in this country recommended values of n will be given.

$n=0.0115$ for glazed pipes and conduits carrying filtered water or water from which deposits or growths do not accrue. The pipes to be practically perfect in both surface and joints.

$n=0.012$ for well-made pipes and conduits with first-class joints, smooth monolithic pipes or tunnels when new and clean. The surface to class as good, but not the equal of glazing. A surface such as is obtained by a "wash coat." To be free from shoulders

¹ Robert Manning first offered his formula in 1889 (Trans. Civil Engineers of Ireland, 1890, Book No. 8, p. 175) in a slightly different form than as now accepted. It has been used extensively by some English and Canadian engineers, but has caused little comment in the United States until within the past two or three years. It is much simpler of solution than the Kutter formula, and there does not appear to be any sacrifice in accuracy if the engineer uses the same values of n to which he has become accustomed. Further comments upon the Manning formula are found under the following citations: The Design of Channels for Irrigation or Drainage, by R. B. Buckley, London, 1911, p. 10; Engin. News, June 17, 1915, p. 1171; Engin. Rec., vol. 75, Mar. 10, 1917, p. 395; Engin. News-Rec., vol. 79, Aug. 9, 1917, p. 277; *id.*, vol. 82, Mar. 13, 1919, p. 536; *id.*, Apr. 3, 1919, p. 685. Prof. H. W. King, of Michigan University, conducted computations that convinced him that the Manning formula is to be preferred to that of Kutter. (Handbook of Hydraulics, by H. W. King, New York, 1918, pp. 198, 403.)

and other obstructions. To convey water from which deposits are not to be expected. May be more freely assumed where high velocities will be attained.

$n=0.013$ for well-made pipes, carefully jointed or monolithic without appreciable shoulders, for waters containing a small amount of sewage. May be used also for designing sewers where conditions are such that high velocities may be attained with flushing streams. Applicable to storm sewers which carry but little deposit-creating material at peak load, but which may have a heavy deposit of grease at the high-water line of ordinary sewage flow. Recommended by Metcalf and Eddy for "concrete sewers under good ordinary conditions of work."¹

The values of n in the Manning formula are sufficiently close to those in the Kutter formula that the same values may be used by engineers partial to the Manning formula. The chief advantage of the latter is its simplicity of computation, but as the Kutter formula is practically never computed outside of a schoolroom—diagrams being quite generally used—this objection is not material.

For those who prefer the William-Hazen formula it would appear that values for C_w of 140, 130, and 120 will quite closely apply to conditions as described for values of n of 0.0115, 0.012, and 0.013, respectively. Figure 6, offered for the general solution of problems by means of the Williams-Hazen formula, may be used for the design of open channels if the value of the hydraulic radius, R , of the prospective water section in the open pipe, be computed into the terms of the equivalent circular section of a full pipe. The value of D , the diameter of the equivalent full pipe, may be computed since $D=4R$.

EXPLANATORY NOTES ON TABLE 11.

Table 11 is similar to Table 3, but contains the data for experiments made on pipes and conduits while they were but partially filled; that is, the surface of the water was exposed to the air. In other words, the pipes and conduits were "flow lines" rather than "pressure lines." With the following additions the explanation for Table 3, page 20, applies to this table also.

Column 2. FF refers to F. C. Finkle, Los Angeles, Calif.

AFB refers to A. F. Bruce, Glasgow, Scotland.

E refers to Boyd Ehle, engineer on construction of Victoria Aqueduct.

JBL refers to J. B. Lippincott, Los Angeles, Calif.

C refers to the late F. C. Coffin.

M refers to F. F. Moore, designing engineer, New York Board of Water Supply.

H refers to Theodore Horton, Albany, N. Y.

P refers to — — Perrone, Italy.

S, as before, refers to the writer.

¹ American Sewerage Practice, 1st ed., New York, 1914, vol. 1, p. 94.

TABLE 11.—*Elements of experiments on partially filled concrete pipes and conduits for the determination of the retardation factors in various formulas.*

1	2	3	4	5	6	7	8	9	10	11	12	13	Coefficients of retardation.					18
													14	15	16	17		
Type No.	Experimenter and year.	Observation.	Inside diameter.	Name and description of pipe.	Length of reach tested.	Maximum depth.	Area of water section.	Wetted perimeter.	Hydraulic mean radius.	Discharge per second.	Mean velocity per second.	Hydraulic grade per foot.	Chey.	Kutter.	Manning.	Bazin (1897).	Williams-Hazen.	
					<i>L.</i>		<i>A</i>	<i>P</i>	<i>R</i>	<i>Q</i>	<i>V</i>	<i>s</i>	<i>C</i>	<i>n</i>	<i>n'</i>	<i>m</i>	<i>C_w</i>	
49	S 37, 1915....	5	10	Jointed concrete pipe chute, Tieton project, U. S. Reclamation Service, Washington; falls 87.6 feet in 935 feet.	Feet. 935	.....	Sq. ft. 0.161	Feet.	Feet. 0.156	Cu. ft. 1.72	Feet. 10.63	Feet. 0.0937	88.6	0.0116	0.0125	0.307	94	
		4	202				.269		.178	2.36	11.67		90.6	.0119	.0125	.311	95	
		3	3				.289		.206	3.45	12.85		92.8	.0118	.0126	.317	95	
		2	2				.310		.221	4.15	13.40		93.3	.0120	.0127	.324	94	
		6	6				.316		.223	4.29	13.59		94.3	.0119	.0126	.317	95	
50a	FF 1.....	.....	22	Mill Creek Power Plant No. 2.	.....	1.75	2.60	5.01	.518	9.80	3.77	.002	117	.0116	.0114	.249	124	
51a	FF 2.....	.....	31	Mill Creek Power Plant No. 3.	.....	2.46	5.15	6.99	.736	19.72	3.83	.002	100	.0142	.0142	.497	101	
52	S 41, 1917....	5	36	Central Colorado Power Co., trunk line near Nederland, Colo.; jointed concrete pipe, laid on a uniform grade as a flow line; nominal slope 0.006.	1,977	1.16 1.73 2.17 2.33 2.37	2.46 4.16 5.04 5.85 5.93	3.97 5.08 5.96 6.41 6.52	.620 .821 .846 .898 .906	16.10 31.70 46.90 48.20 49.50	6.56 7.62 8.11 8.25 8.34	.00507 .00501 .00496 .00512 .00508	117 119 125 122 123	.0121 .0124 .0119 .0123 .0123	.0117 .0121 .0115 .0120 .0119	.273 .286 .237 .279 .274	117 114 120 116 117	
53a	FF 3, 1904, 1908.	1	36	Lytle Power Plant, California. Same pipe, 4 years later.	.....	2.88 2.88	6.97 6.97	8.29 8.29	.840 .840	20.10 21.20	2.88 3.04	.001 .001	100 105	.0145 .0138	.0145 .0138	.538 .460	102 107	
54a	E 1, 1915....	2	42	Victoria Aqueduct, B. C., Canada; tests made on flow line when new; pipe, including joints, exceedingly smooth; water clear; alignment sinuous.	800	.72 1.21 1.67 2.17 Full.	1.42 2.97 4.52 6.25 9.62	3.27 4.39 5.34 6.34 10.99	.434 .677 .846 .986 .875	3.36 9.30 16.92 26.00 40.59	2.37 3.43 3.74 4.16 4.22	.001 .001 .001 .001 1.001	114 121 129 132 143	.0115 .0118 .0118 .0116 .0106	.0114 .0116 .0112 .0112 .0102	.255 .253 .205 .188 .098	127 127 132 133 145	
55a	E 2, 1915....	1	42	Victoria Aqueduct, B. C., Canada; same general description as for above; this reach near outlet, 27 miles from that above, which is near inlet.	800	.67 1.15 1.62 2.08 3.00	1.28 4.25 4.34 5.96 8.78	3.05 4.25 5.23 6.16 7.68	.420 .644 .830 .967 1,143	2.78 8.52 16.32 25.23 39.78	2.17 3.11 3.76 4.23 4.53	.001 .001 .001 .001 .001	106 122 130 136 134	.0121 .0116 .0114 .0113 .0117	.0121 .0113 .0110 .0108 .0112	.315 .229 .189 .154 .187	119 130 134 137 132	
56	S 49, 1916....	5	42	Victoria Aqueduct, B. C., Canada; longer reach near inlet; tested 15 months after those above.	1,966	1.26 1.30 1.65 1.88 2.08	3.11 3.24 4.47 5.27 5.94	4.50 4.57 5.30 5.76 6.20	.691 .710 .843 .916 .938	9.69 11.45 18.86 24.34 27.99	3.11 3.53 4.22 4.62 4.71	.00105 .00103 .00104 .00106 .00108	115 132 142 148 146	.0124 .0110 .0106 .0104 .0105	.0121 .0108 .0101 .0099 .0101	.307 .183 .095 .062 .076	121 137 146 150 147	

58a	JBL 1.....	1	San Gabriel Tunnel No. 15, Calif.	446	3.13	14.08	10.71	1.310	70.80	5.01	.00126	123	.0128	.0126	.320	118
59a	JBL 2.....	2	San Gabriel Tunnel No. 23, Calif.	318	3.50	15.73	11.50	1.370	74.64	4.74	.00082	142	.0113	.0111	.133	136
60a	JBL 5.....	5	Old Los Angeles Aqueduct, Calif.	700	.....	5.00	6.12	.817	13.55	2.71	.00051	133	.0111	.0106	.170	140
	JBL 6.....	6			.....	5.16	6.22	.830	14.51	2.81	.00051	137	.0109	.0106	.140	144
61a	FB.....		Loch Katrine Aqueduct, Glasgow; a basket-handle-shaped conduit, 9 feet high by 10 feet maximum width; concrete deposited against soaked wood forms made of tongue and groove lumber; reach straight.	6, 760	1.72	14.20	.....	1.227	26.62	1.87	.000182	125	.0123	.0122	.289	131
					2.16	18.30	.....	1.471	37.86	2.07	.000182	127	.0125	.0125	.299	128
					2.16	18.30	.....	1.471	38.57	2.11	.000182	129	.0123	.0123	.270	131
					2.22	18.70	.....	1.490	41.42	2.22	.000182	135	.0119	.0117	.295	137
					2.21	18.80	.....	1.498	39.99	2.13	.000182	129	.0124	.0123	.274	131
					2.22	18.80	.....	1.500	40.70	2.16	.000182	130	.0123	.0122	.256	133
					2.30	19.70	.....	1.547	42.89	2.18	.000182	130	.0124	.0123	.269	132
					2.42	20.70	.....	1.569	45.83	2.21	.000182	129	.0125	.0124	.278	131
					2.43	20.90	.....	1.607	46.58	2.23	.000182	131	.0125	.0123	.264	131
					2.44	20.90	.....	1.610	46.58	2.23	.000182	130	.0125	.0124	.271	131
					2.46	20.70	.....	1.621	46.34	2.24	.000182	131	.0124	.0123	.263	132
					2.48	21.30	.....	1.627	48.09	2.26	.000182	131	.0124	.0123	.261	132
					2.73	23.70	.....	1.740	53.50	2.26	.000182	127	.0129	.0128	.321	127
62a	P, 1896.....		Aqueduct of the Sorrino, Italy.					1.410	.....	4.06	.00050	152	.0107	.0103	.042	150
63a	F-S, 1880.....		Sudbury conduit, Boston water works; plaster of pure cement over hard brick.	490	3.071	.....	.....	1.873	.....	2.526	.000161	146	.0114	.0113	.109	145
					3.574	.....	.....	2.048	.....	2.672	.000160	148	.0114	.0114	.096	145
					3.768	.....	.....	2.111	.....	2.805	.000158	154	.0111	.0109	.085	150
64a	C.....	1	Conduit, Cambridge, Mass.		1.75	.....	.....	.....	.....	.....	.00025	.....	.0110	.....	.....	.....
65a	H, 1896.....	1	North Metropolitan sewerage system; East Boston pumping station; cement-washed brick trunk sewer.		1.02	3.96	6.39	.619	6.10	1.58	.000333	110	.0122	.0125	.340	122
		2			1.52	7.11	7.66	.928	15.67	2.21	.000333	126	.0117	.0117	.245	133
		3			2.04	10.85	8.98	1.208	29.40	2.70	.000333	134	.0116	.0114	.187	137
		4			2.45	14.00	9.95	1.408	42.18	3.03	.000333	139	.0115	.0112	.159	140
		5			3.16	19.92	10.88	1.850	69.50	3.48	.000333	141	.0117	.0117	.159	136
		6			3.75	25.12	12.57	1.999	94.60	3.73	.000333	145	.0116	.0115	.128	138
		7			4.62	32.86	14.24	2.309	138.00	4.18	.000333	150	.0115	.0113	.069	141
66a	H, 1897.....	1	Same reach of pipe, 16 months later.		2.15	11.67	9.12	1.280	30.13	2.55	.000333	123	.0126	.0125	.313	125
		2			2.74	16.42	10.53	1.560	47.75	2.90	.000333	127	.0127	.0126	.298	126
		3			3.19	20.15	11.44	1.762	62.05	3.06	.000333	126	.0129	.0129	.328	123
		4			3.20	20.22	11.42	1.771	64.82	3.18	.000333	131	.0126	.0125	.272	127
67a	H, 1900.....	1	Same reach after another lapse of 28 months.		1.99	10.44	9.32	1.120	24.96	2.38	.000333	123	.0124	.0123	.295	127
		2			2.83	17.10	10.66	1.606	48.26	2.82	.000333	121	.0132	.0132	.383	120
		3			3.64	25.08	12.85	1.952	76.78	3.16	.000333	124	.0133	.0134	.379	119
		4			4.18	28.89	13.57	2.130	95.84	3.30	.000333	124	.0136	.0136	.398	117

¹ In these tests the nominal or constructed slope of the pipe was accepted as the hydraulic grade. This probably does not introduce any error of moment, with the possible exception of observation 5 of pipe No. 54a, where the pipe was full, that is, under more or less pressure, which would have supported water columns at either ends of the reach tested, to such elevations that some other than the nominal slope might have been indicated, especially as the reach was relatively short, being but 800 feet long.

TABLE 11.—*Elements of experiments on partially filled concrete pipes and conduits for the determination of the retardation factors in various formulas—Con.*

1	2	3	4	5	6	7	8	9	10	11	12	13	Coefficients of retardation.				18
													14	15	16	17	
Pipe No.	Experi- menter and year.	Ob- serva- tion.	Inside diam- eter.	Name and description of pipe.	Length of reach tested.	Maxi- mum depth.	Area of water section.	Wetted per- imeter.	Hy- draulic mean radius.	Dis- charge per second.	Mean velocity per second.	Hydraulic grade per foot.	Chezy.	Kutter.	Man- ning.	Bazin (1897).	Wil- liams- Hazen.
			<i>d</i>		<i>L</i>	<i>F_{ect}</i>	<i>Sq. ft.</i>	<i>F_{ect}</i>	<i>R</i>	<i>Q</i>	<i>V</i>	<i>s</i>	<i>C</i>	<i>n</i>	<i>n</i>	<i>m</i>	<i>C₉₀</i>
68a	H, 1896.	1	<i>In.</i>	North Metropolitan sewerage system, below Charleston pumping station; basket-handle shaped, 6 feet by 6 feet 8 inches; 10 months in use.	<i>F_{ect}</i>	<i>F_{ect}</i>	<i>Sq. ft.</i>	<i>F_{ect}</i>	<i>F_{ect}</i>	<i>Cu. ft.</i>	<i>F_{ect}</i>	<i>F_{ect}</i>	107	.0129	.0132	.392	116
		2	.....		5,000	1.02	4.32	6.28	.688	8.60	1.99	.0005	112	.0131	.0133	.394	116
		3	.....			1.44	6.75	6.98	.958	16.59	2.46	.0005	115	.0132	.0134	.395	116
		4	.....			1.91	9.50	8.01	1.187	26.81	2.82	.0005	118	.0133	.0133	.395	118
		5	.....			2.40	12.40	8.95	1.387	38.82	3.13	.0005	124	.0130	.0130	.338	121
69a	H, 1897.	1	.....	Same reach 16 months later.	.....	2.91	15.00	9.76	1.540	45.67	2.97	.0005	107	.0149	.0151	.589	104
		2	.....			3.29	17.90	10.96	1.650	56.67	3.16	.0005	110	.0147	.0148	.557	106
70a	H, 1900.	1	.....	Same reach; after another lapse of 29 months.	.....	2.29	11.60	8.65	1.342	30.82	2.66	.0005	102	.0151	.0154	.620	102
		2	.....			2.78	14.50	9.60	1.508	41.39	2.86	.0005	104	.0152	.0155	.633	102
		3	.....			3.26	17.40	10.60	1.645	52.96	3.04	.0005	106	.0152	.0154	.626	103
71a	M, 1915.	2	.....	Cut-and-cover section, Catskill Aqueduct, Esopus division, stations 770+09 to 834+72.	6,463	4.54	71.80	23.90	3.000	261.40	3.64	.00021	145	.0123	.0123	.151	134
		1	.....			5.40	86.60	25.70	3.370	346.50	3.99	.00021	150	.0121	.0121	.096	134
		3	.....		12,277	4.35	68.40	23.60	2.900	261.40	3.82	.00024	144	.0123	.0123	.161	133
		2	.....			5.22	83.40	25.30	3.290	346.50	4.15	.00024	147	.0123	.0123	.131	134
		4	.....	Stations 131+57 to 254+34.		6.50	105.50	27.90	3.780	468.70	4.44	.00024	147	.0125	.0126	.140	131
		1	.....			6.43	104.30	27.70	3.770	471.80	4.53	.00024	151	.0122	.0123	.085	135
		3	.....		7,708	8.00	131.00	30.90	4.240	625.00	4.77	.00024	149	.0125	.0126	.119	131
		2	.....			7.85	128.50	30.60	4.200	621.90	4.84	.00024	152	.0123	.0124	.098	134
		1	.....	Stations 131+57 to 208+65.		8.78	143.90	32.50	4.430	736.50	5.12	.00024	157	.0120	.0120	.008	137
		1	.....		4,660	9.26	151.70	33.50	4.530	756.50	4.98	.00024	151	.0125	.0125	.093	132

DESCRIPTIONS OF PIPES.

The following descriptions apply to experiments conducted by the writer for the Bureau of Public Roads. The pipes were laid on a hydraulic gradient and in no case were they flowing full of water. For descriptions of experiments conducted under similar conditions by other agencies see Appendix, page 77.

No. 49, Experiment S-37.—10-inch jointed concrete pipe chute-drop on L-Y-7 line, Tieton project, United States Reclamation Service, Washington.—Some of the topography of the Tieton project is such that water for irrigation must be conveyed down very steep slopes from one open channel to another. For this purpose chute drops of both the open type and the pipe type are used. A series of experiments was conducted on one of the pipes.

Water from the upper canal is delivered through the bank into a pool just above a 4-foot Cipolletti weir. After the water falls over this measuring weir it drops down a 16-inch intake well about 2 feet deep. At the bottom of this well the pipe chute, 10 inches in diameter, leads down the hill; falling 87.6 feet in a developed distance of 935 feet.

The volume of water, Q , was determined by hook-gauge measurements of head on the 4-foot weir, where the contraction conditions were good and the velocity of approach reduced by a brush screen. All of the items in Table 11 are based on the general

hydraulic assumption that $A = \frac{Q}{V}$. As we have determined Q and V ,

we can solve for A as for a segment of 10-inch pipe. The resulting retardation factors for various formulas are all right in so far as they might be used in computing the velocity down a similar chute, but may not be used in the computation of maximum capacity for the following reason. All complete experiments upon friction losses in chute drops of either the open-channel or pipe type have developed the fact that the measured area of the wet cross section is much

greater than $\frac{Q}{V}$. By a "complete experiment" is meant one in

which Q , V , and the wet cross section, which we will call A' , were measured independently. Such measurements disclose the fact that $Q = (A' - A'')V$ where A'' is an area made up of the aggregate entrained air bubbles. As a concrete example take observation 6 (see Table 11, p. 68). The velocity, V , as measured was 13.59 feet per second. The quantity, Q , as measured over the weir, was 4.29

second-feet. What might be termed the net water area $A = \frac{Q}{V}$ was

0.316 square foot. The nominal area of a 10-inch pipe is 0.545 square foot, but as most small pipes run under size the actual area was probably nearer 0.5 square foot. Thus, while by computation but 54 per cent of the cross section of the pipe was filled, yet the intake pool was full and no more water could be crowded into the chute. In other words, the pipe was filled with a mixture of air and water. At the outlet of pipe chutes running to capacity this fact is manifest by periodic rushes of air into the outlet pool.

It is not feasible and perhaps not possible to determine the mean area of the water section down a pipe chute by actual measurements. If such a thing were possible, then retardation factors could be com-

puted, from which other similar chutes could be designed from a capacity standpoint without regard to the actual velocity attained. However, we do know, from experiments made on open-channel concrete chutes, that the value of n in the Kutter formula must be raised 0.002 to 0.004 when a chute is designed from a capacity standpoint.¹ In other words, the series of experiments on this 10-inch pipe chute indicates that a value of n of about 0.014 or 0.015 should be used in designing for capacity, instead of the values as shown in Table 11, namely, about 0.0119.

A view of one of these pipe chutes, in course of construction, and showing the vertical curve mentioned above, is given on Plate XXVIII in Volume II of Prof. Etcheverry's work. The writer believes this view is of the 10-inch chute discussed above.

No. 52, Experiment S-41.—36-inch jointed concrete flow line, Colorado Power Co., near Nederland, Colo.—In 1909 a flow-line conduit 12 miles in length was laid down the canyon of Middle Boulder Creek from the dam at Barker Reservoir to a small reservoir about 4 miles from Boulder, Colo., and about 2,000 feet in elevation above the creek bottom, where one of the plants of the Colorado Power Co. is located. This conduit is laid on an even gradient of 5 feet per 1,000 feet of pipe, except where inverted siphons are required to cross gulches and draws leading into the canyon. An article describing this installation says:²

The 3-inch shell of the pipe that is laid on the hydraulic grade consists of one part Portland cement and three parts aggregate, graded from sand to stones having a maximum dimension of 1 inch. The pipe was cast in sections 2 feet long, with socket on one end and a bevel on the other end of each section to form the joints. Each section contains two hoops of No. 5 steel wire having a high tensile strength, one hoop being placed 6 inches from each end. These hoops are not considered to be of much value as reinforcing, but rather as an aid in preventing breakage before the concrete has set. The line of the conduit is very crooked, the longest tangent not exceeding 500 feet. Straight and beveled pipe were employed together to build the conduit on curves. The latter were located so their radii were as nearly uniform as possible, requiring only two kinds of beveled pipe.

The mixture was placed in rather dry layers 3 inches thick and carefully tamped. This allowed the forms to be pulled immediately after which the pipe section was kept thoroughly wet for 7 days, then the inner surface of the sections was coated with a thick wash of neat cement to fill all irregularities. This surface was thus finished quite smooth, and, with the manner in which the joints were made, produced a conduit having a large carrying capacity.

During the season of 1915 the writer conducted a series of experiments upon the carrying capacity of a portion of this conduit near the upper end. A reach 1,977 feet long was chosen. Open standpipes near each end of the reach and approximately each 500 feet between the ends gave opportunity for measurement of the pipe segment not occupied by the water at five evenly spaced stations on the reach. For each run the quantity of water flowing in the pipe was varied by regulation of the outlet gates of Barker Reservoir. The velocity of the water in the flow line was determined by accepting

¹ The fact that the fundamental hydraulic equation $Q = A V$ does not hold for chute drops, where high velocities, wave action, and turbulence exist, was first called to the attention of the writer by Mr. W. G. Steward, of the United States Reclamation Service. The results of his experiments, which have been corroborated in essentials by those of the writer, are found in *Irrigation Practice and Engineering*, by B. A. Etcheverry, Vol. III, p. 261.

² *Engin. Rec.*, Nov. 6, 1909, vol. 60, p. 514.

the mean velocity of four batches of fluorescein for each observation. The color was injected at the standpipe marking the upper end of the reach and observed at a similar standpipe marking the lower end of the reach. The slope of the water surface was determined by piezometer tubes of type A connected with gauge glasses outside the pipe. The piezometer tubes were under identical dynamic conditions and examination of column 13, Table 11, shows that the corrected observed slopes practically agree with the nominal slope of the conduit. It was necessary to correct the observed slope for changes in velocity head between the upper and lower ends of the reach, the flow not being uniform throughout the reach tested. It is the writer's opinion, based upon his experience, that "uniform flow" is an ideal that is assumed in design but seldom attained in practice.

The pipe was designed under an assumed value of n in the Kutter formula of 0.012 and observations made by the writer prove this assumption to have been correct, even after a period of 6 years without cleaning. So far as examination of the interior could be made from the various manholes the conduit is clean and practically free from slime. As the water comes from a large reservoir located on a mountain stream, it is clear and cold at all seasons of the year.

No. 56, Experiment S-49.—42-inch jointed reinforced concrete pipe, Victoria Aqueduct, Vancouver Island, British Columbia, Canada.—As mentioned under the descriptions of Nos. 30, 54*a*, and 55*a*, the Victoria Aqueduct consists of about 27 miles of flow line, broken by six inverted siphons (Pl. V, fig. 3, is typical of this flow line). Simultaneously with the experiments conducted on siphon No. 1 (pipe No. 30, p. 39) readings were also taken on gauges at manholes 3 and 4. This reach of pipe, 1,986 feet long, is downstream from the reach 800 feet long tested by Ehle in 1915 (No. 54*a*). Piezometer tubes of type A, under identical dynamic conditions, were held upstream against the current at the two manholes. True siphon tubes were carried over the edge of the manholes and connected the piezometers with graduated gauge glasses. The gauge glasses were then considered in a scheme of levels and the fall of the water surface was thus determined. This method is probably more accurate than to accept the nominal slope of the pipe. The areas of the water sections at the ends of the reach for the various runs were determined by careful measurements in the manholes. The discharge of the pipe was taken as the velocity in feet per second (determined by color tests in siphon No. 1), multiplied by the mean area of the siphon interior (p. 41). This discharge, divided by the mean area of the water section in the flow line, gave the velocity within the flow line. The reach tested was typical of the whole aqueduct, being about half curve and half tangent. The friction factors confirm those found by Ehle and show the same decrease in the values of n as the depth of water (consequently the velocity and the hydraulic radius for the depths considered) is increased. It was not feasible at the time these tests were made to turn sufficient water into the pipe line to fill completely the flow section, as a repair, due to a hillside slip several miles downstream, was in progress. The values of the retardation factors show that 0.011 is probably as low a value of n as is feasible to obtain in a commercial pipe and should only be used for pipes under practically ideal conditions, such as hold on this aqueduct.

CONCLUSIONS.¹

From the facts developed in this investigation the following conclusions appear to be warranted.

In considering the design of a concrete pipe or conduit, from a capacity standpoint, the fundamentals to be kept in mind are:

- (1) Original interior surface.
- (2) Engineering; inspection and supervision of construction.
- (3) The water.
- (4) Acquired interior surface.

In a jointed pipe, the original interior surface depends upon that of the individual units and of the assembled whole. The smoothest units are cast of a wet mixture and allowed to set in rigid, smooth, oiled forms. These units are true to shape and assemble into a nearly perfect pipe. As the joints are practically as smooth as the cast surface, the number of joints is almost immaterial.

Most processes that permit immediate removal of the forms do not protect the plastic concrete against distortion. Distortion in the units means offsets in the pipe that may easily decrease the capacity from 10 to 20 per cent. This percentage may be reduced after assembling the units by tapering down the offsets with mortar applied with a trowel.

Supervision of the finished joints will usually improve the capacity materially. The good results obtained with the band method (see p. 85) appear perfectly feasible.

A brush coat applied to a rough original interior will increase the capacity and decrease the percolation. The same coat applied to a smooth interior will decrease its capacity and is not needed, under ordinary pressures, to prevent percolation, if the pipe is properly made. This is true for the reason that methods used in making pipe with a smooth interior are also conducive to a dense concrete. Note the suggestion that coating may scale off if radically different mixtures are employed for pipe and coat. (See p. 99.)

Pipe units made with the molds now on the market usually run undersize by as much as 3 or 4 per cent (in area) for diameters under 20 inches. Above that size, the nominal and actual areas are more nearly equal. Most pipes made with a wet mixture in short units, from which the molds are immediately stripped, "slump" to a slight extent, making a section somewhat undersize in area with a slight excess in shell thickness.

From a capacity standpoint monolithic pipes and conduits are built under two general conditions: (1) In the open or in the comparative freedom of a trench; (2) in a tunnel. Under the first condition the form adjustment, bracing, supervision, concreting, spading, and final inspection can be conducted from both inside and outside, with the added advantage of working in the daylight. Naturally this tends to result in better workmanship and higher carrying capacity than is feasible in a tunnel where all of the above operations

¹ These conclusions were written since receipt of the discussions beginning on p. 92, and are, therefore, based on all the data in the paper.

must be done from the inside alone under the shadows and imperfections of artificial lighting.

For all shapes, circular or otherwise, the invert is usually laid first. Forms for the remainder of the section are then placed on the invert and the section completed. Sometimes the first pouring extends just across the bottom and sometimes is carried up to the spring line. This depends on shape and size of the section. Smooth joints between the pourings and between the ends of adjoining set-ups are difficult to attain. Unless very heavily braced, the pressure of the head of wet concrete will spring the forms and result in offsets. On the Catskill aqueduct this amounted to as much as 0.15 foot.¹ The writer has seen cases where contractions of from 2 to 4 inches were made in sections 5 feet or less in diameter. Other factors that influence this movement are weather, length of sections, rapidity of filling the forms, and the type of aqueduct.¹

Before the advent of steel forms, engineers anticipated a rough interior when the forms were stripped and relied on a plaster coat to fill interstices, estimates of cost being based on that of a plaster coat on a certain sized conduit equated against that of an unplastered surface on a larger conduit.² The present practice in general is to use smooth steel forms; clean them thoroughly after each casting, then dry and oil or grease them before using again. If close attention is given to spading the mixture into close contact with the forms, then a surface is secured that is smoother than will be attained by adding a plaster coat, local roughness alone being improved by pointing up and chipping down. The crown in particular is liable to be rough.¹

Experience indicates that a given surface is more assuredly repeated in a pipe of precast sections than of monolithic construction. Thus a smaller factor of safety in the way of capacity overload may be assumed for precast pipe. The experiments indicate that some of the smoothest pipe is of careful monolithic construction; likewise some of the roughest. Thus, while a very smooth surface may be attained, it can not be anticipated with the assuredness possible where units are precast under the best practice and subject to the conditions attainable in a pipe yard.

For all types of pipe, competent engineering supervision and inspection are necessary if the best results are to be obtained. Velocity and entry heads should be provided at the intake. Alignment and grades should be true. Changes in either should be made with as gentle curves as are feasible. Unless it is excluded above the intakes, means should be provided for the removal of débris at the foot of steep *upward* slopes. Means for the removal of air, not only at the summits but also near the intake (unless deeply submerged) should be provided. This is true of small orchard lines as well as large siphons. Trash racks, originally placed at the intakes of many siphon pipes, have since been removed in many cases because the danger from washout, due to the accumulation of trash, outweighed the good accomplished.

For all practical purposes it does not appear necessary to limit the higher velocities. The velocity should be at least sufficient to prevent the deposition of silt—probably not lower than 3 feet per second.

¹ Water Works Handbook, by Flinn, Weston and Bogert, New York, 1916, p. 276.

² Jour. West. Soc. Engrs., Vol. XVI, No. 8, 1911, p. 696. Discussion of C. C. Saner.

More or less slime may be expected from waters stored in reservoirs containing algæ growths or from waters that have been conveyed long distances in openearth channels. (See Mr. Hazen's discussion on p. 97). This may also be true, but to a less extent, if the open channel is of wood or concrete. Waters of the Southwest are less liable to develop retarding growths in covered conduits than those of the East and Northwest. Water containing calcium carbonate (CaCO_3) will smoothly coat pipe of any material. If sand, gravel, or other débris is also present in the water, the cemented accretion will be much more harmful, being rough and more rapid.

After construction a rough pipe may become somewhat smoother if conditions are such that a mineral coating is deposited. An originally smooth surface will remain about as constructed or depreciate slightly by mineral or slime deposits. Slimes come quickly or not at all. A depreciation of from 10 to 15 per cent in capacity can occur within five to seven months, but does not greatly increase after that. Thus, to be of material benefit, cleaning must be frequent if necessary at all. For this reason periodic cleanings have been abandoned in many places.¹ If algæ slimes are anticipated, it may be best to allow for 15 per cent depreciation of capacity and no cleaning.

A concrete surface is not subject to a progressive roughening influence like the tuberculation found in iron and steel pipes, though tuberculation of the reinforcement may occur if too near the surface. Roots may affect a poorly made or poorly laid pipe, but will not influence a hard, well-jointed pipe.

In considering various kinds of pipes it is not sufficient to compare concrete with wood, concrete with steel or iron, concrete with vitrified clay, or even concrete with concrete. This is true not only from a capacity standpoint, but also from the standpoint of strength, life, and operation. One particular class of concrete pipe must be compared with the pipe of the other materials or with concrete pipes of the other classes. Two estimates or bids for a concrete pipe may differ 20 per cent, yet from a capacity standpoint alone the higher in cost may be the more economical.

ACKNOWLEDGMENTS.

The writer desires to acknowledge indebtedness to the various engineers and managers of irrigation, municipal, and power systems who permitted and aided in tests upon the pipes in their charge; also to the Board of Water Supply of New York City and to the Ontario Power Commission of Toronto, Canada, for supplying hitherto unpublished results of tests made on their conduits.

Tests made on pipes of the various United States Reclamation Service projects were made under a cooperative agreement between that service and this bureau. Especial acknowledgment is due the officers and men of the Reclamation Service who were unfailingly courteous, energetic in getting the best feasible conditions for experimentation, and in many cases devoted to these tests long hours outside their regular work.

¹ Water Works Handbook, Flinn, Weston and Bogert, New York, 1916, pp. 290-291.

APPENDIX.

The following pages are devoted to abstracts of the descriptions of experiments made by agencies other than the Irrigation Division, Bureau of Public Roads. The first part covers tests made on pipes under pressure while the last portion covers tests made on pipes and conduits but partially filled. The number before each description refers to the corresponding numbers in column 1, Tables 3, 4, and 11.

PRESSURE PIPES.

No. 12, Experiment N-1.—16-inch jointed concrete pipe, Z_a , siphon, Umatilla project, United States Reclamation Service, Oregon.—In 1911 and 1912 Herbert D. Newell, manager of the Umatilla project, conducted a series of experiments on several of the concrete inverted siphons under his charge. For the sake of brevity the descriptive matter pertaining to all the tests will be abstracted from his extended article,¹ and placed under this number. Matter pertaining to individual pipes will be placed under the proper reference number. He states:

During 1911 and 1912 a number of experiments were made to determine the coefficient of friction. The quantity of water was generally determined by meter measurements. Difference of water surface elevation between the inlet and outlet ends were determined from bench marks carefully established on the inlet and outlet structures.

Regarding the 16-inch pipes he adds:

No information exists as to whether or not the 16-inch pipes are somewhat obstructed near the bottoms of depressions. It will be noted that the 16-inch pipe show discharges relatively much smaller than the 30 and 46 inch pipe. The 16-inch are made by the dry process and have joints every 2 feet. At every joint there is unavoidably a slight irregularity in the cross section. The mixture used in making the 30 and 46 inch pipe is distinctly a wet mixture. All sizes are grouted on the inside, but the grouting on the large size is more smooth, as a man can work inside the pipe and it is possible to do a better job.

The nominal size of the pipe appears to have been accepted as the true size. In the experiment on this particular siphon the quantity of water for the first observation was taken as the mean of two meter measurements, one indicating a discharge of 3.78 second-feet and the other 3.70 second-feet. For the second observation the mean of three measurements, ranging from 4.78 to 4.97 second-feet was accepted.

From the amount of the friction loss the writer would judge that some débris had accumulated between the time this pipe was laid and the date of the experiments. The retardation factors are not consistent.

No. 13, Experiment N-2.—16-inch jointed concrete pipe, Z_c , siphon, Umatilla project, United States Reclamation Service, Oregon.—In addition to the information given under reference number 12a for the series of tests conducted by Newell, the following pertains to this pipe alone:

¹ Studies of Coefficient of Friction in Reinforced-Concrete Pipe, Umatilla project, Oregon. By H. D. Newell, Eng. News, vol. 69, May 1, 1913, p. 904.

The quantity was taken as the mean indicated by two current meter tests, one giving 3.19 and one giving 3.65 second-feet. This agreement is not as close as it should be. For this reason the writer would not give too much weight to the results of the experiments on this pipe in considering the friction loss which appears rather low for this type of pipe. The pressure head was measured by a "testing gage." The one observation on this pipe shows a value of $C_s = 0.314$.

No. 19, Experiment.—Fanning 20-inch cement-lined wrought-iron force main pipe.—In 1880, J. T. Fanning conducted a series of experiments and listed the results in his well-known work on hydraulics,¹ but he does not give a description of the pipe or of his methods of experimentation. Hering and Trautwine say of this pipe:²

No short bends, but two large Y branches, two small blow-off branches, and three stop valves.

No. 24, Experiment N-3.—30-inch reinforced concrete jointed pipe, D₁ siphon, Umatilla project, United States Reclamation Service, Oregon.—This pipe, laid in the winter of 1909–10, was tested for capacity by Mr. Newell in 1911 and by the writer in 1915. (See No. 23.) For general data on the Newell tests see No. 12a.

The elevations of the surface of the water at the inlet and outlet structures were determined by the use of a hose pipe and water pail, in a manner similar to that later used by the writer when other methods were not feasible. By means of a true siphon over the wing walls the surface of the water in the pail and in the canal are brought to the same level.

For observation No. 1 a single weir measurement was accepted as indicating the discharge, while for observation No. 2 a single meter measurement indicated a discharge of 16.62 second-feet and a measurement at the weir at the inlet indicated a discharge of 17.04 second-feet. As noted in Table 2 the various elements have been computed for both these indicated discharges, rather than averaging them. This method follows Mr. Newell's original article.

A comparison of the platted points for this pipe (Pl. VI) indicated that it was very smooth when new, but had become somewhat obstructed when tested by the writer four years after Mr. Newell's tests. The relationship of the leading canal to the intake clearly shows that this is highly probable. The average value of C_s for the three observations equals 0.408, which is higher than usual, even for the best of construction.

No. 25, Experiment N-4.—30-inch reinforced concrete jointed pipe, R₃ siphon, Umatilla project, United States Reclamation Service, Oregon.—This pipe was tested by Mr. Newell when it was in its fourth season of service. The discharge was taken as the mean of three measurements by current meter, ranging from 12.76 to 12.42 second-feet, to which was added 0.032 second-foot which passed a weir. Mr. Newell states: "It is not unlikely that there is a considerable deposit of sand in the first low depression." This would not appear to the writer to be a serious deposit, as the friction loss indicates a very efficient pipe. The relatively great length of the reach, 3,658 feet, makes this a valuable test, so far as one observation is indicative. The value of C_s equals 0.351.

¹ A Practical Treatise on Hydraulic and Water Supply Engineering, by J. T. Fanning, 11th ed., New York, 1893, p. 238.

² E. Ganguillet and W. R. Kutter, translated by Rudolph Hering and John C. Trautwine, jr. A General Formula for the Uniform Flow of Water in Rivers and Other Channels. New York, 1907, 2d ed., p. 154–155.

For additional general information which also applies to this pipe see No. 12a.

No. 27, Experiment B-1.—31.5-inch (0.8 meter) experimental conduit, Dijon, France.¹—In 1895, M. Henry Bazin conducted a series of experiments upon “a cement pipe, 0.80 meter (31.5 inches) in diameter and 80 meters (262 feet) long. This pipe was straight, perfect in bore, and opened at its extremities into two basins, 2 meters wide and 15 meters long, having vertical walls.”

The velocities in the pipe were measured with a pitot tube, operated in one of three shafts, which divided the pipe into four equal parts. Each of these shafts was the full width of the pipe, 0.8 meter, and 0.8 meter in length, measured along the axis of the pipe. The discharge was also measured over a sharp-edged rectangular weir 2.01 meters wide, without end contractions, located 50 meters beyond the lower basin. The coefficient of discharge of this weir had been previously established.

The loss of head was determined over a reach of 40 meters (131 feet) between the two end shafts. “On the right of each shaft was installed a manometer, consisting of a glass tube with a scale, the former being connected with the interior of the pipe by an orifice 0.002 meter in diameter, pierced in the wall, without any protuberance.” Considering the shortness of the reach, reference to Plate VI shows a remarkably consistent set of observation points, indicating an exponent of V equal to 1.971 and values of C_s equal to about 0.418. If this value of C_s truly represents the condition of this conduit, then a surface smoother than that of the Victoria Aqueduct is indicated, even considering the curvature of the latter. To the writer this is almost inconceivable, in commercial construction.

No. 33, Experiment N-5.—46-inch reinforced concrete jointed pipe, R_1 siphon, Umatilla project, United States Reclamation Service, Oregon.—This pipe, laid in the winter of 1909–10 was tested in 1911 and again in 1912 by Mr. Newell and in 1915 by the writer. (See No. 32.) In 1911 the elevations of the water surface in the inlet and outlet structures were determined by the use of hose and pail, mentioned under No. 24a, and in 1912 a “testing gauge” was used. A close agreement resulted between the two methods of gauging. The experiments by both Mr. Newell and the writer indicate that this is a very efficient pipe. Although not so smooth as the Victoria Aqueduct the absence of curvature gives about the same friction factors. For general information that also applies to this pipe see No. 12a.

No. 36, Experiment of Budau.—7.22 foot reinforced concrete pipe, Perlmoos cement works, Sell-Leukenthal, Austria.²—Prof. A. Budau conducted a series of tests upon a new pipe line serving a power plant. This conduit was 4,200 feet long and 7.22 feet inside diameter. No mention is made in the elaborate description of the tests as to whether the pipe is jointed or monolithic, made over wood or steel forms, coated or as left by the forms, exactly the nominal size or otherwise. The line has several curves in horizontal alignment, but each one covers such a small angle that from the standpoint of capacity the pipe may be considered straight. In profile the pipe is on a continuous gentle down grade. Loss of head was measured with water

¹ Trans. Amer. Soc. Civ. Engin., vol. 47 (1902), p. 246.

² Experiments on pressure losses in iron reinforced concrete conduits, by Prof. A. Budau, from the “Zeitschrift des Oesterr. Ingenieur und Architekten-Vereins No. 8,” Feb. 20, 1914, p. 141.

columns in graduated glass tubes, installed at each end of the reach tested. The relative elevations of these gauges were established by the static head; that is, with still water in the line. The piezometer connections were of type D (fig. 3), different from anything used in American experiments, so far as the writer is informed. A perforated brass ball, 30 millimeters in diameter, was set at the center of the pipe. In order to annul all influence of velocity head and secure only pressure head, the balls were filled with brass shavings. The usual tubing connection is made between the balls and the gauge glasses, through stuffing boxes set in the shell of the pipe.

The volume of water was measured over a specially formed weir, having end contractions.

Piezometer No. 1 was located about $1\frac{1}{2}$ diameters from the intake of the pipe line. This would appear to be at a point subject to much disturbance. The weir is located about 8 or 10 feet below the power house and no mention is made of baffles to still the velocity of approach. These conditions may offer grounds for criticism of this series, although the platted points appear to be consistent with the exception of observation No. 3, which was excluded by the writer in consideration of this series, as there is probably some error of observation or typography.

No. 38, Experiment M-1.—110-inch siphons, Catskill Aqueduct, New York.—The Catskill Aqueduct contains several pipe siphons using identical construction for inlet and outlet chambers and for the siphon proper. The latter is in essentials a steel pipe, lined with 2 inches of cement mortar and protected outside with at least 6 inches of concrete.¹

One siphon was lined with a cement-gun process while the others were grouted. For both processes, the invert, for a width of about 8 feet of arc, was lined in the manner employed in laying sidewalks. When the cement gun was used the coat was applied in layers in rapid succession. Each layer is sufficiently rough for a secure bond with the next one. The resulting surface was floated and troweled to secure a smooth finish. The cement-gun process was abandoned by the contractor after one siphon had been so lined. In the grouting method, metal-covered wood forms were used after extensive experimentation. The grout was placed through a $2\frac{1}{2}$ -inch pouring pipe inserted in a rivet-passing hole and subjected to a head of about 4 feet above the zenith of the pipe. The first batch or two of grout for each set-up, 15 feet in length, was mixed 1 part cement to 1 of sand while the succeeding batches were mixed in a ratio of 1 to 2. By both processes "very smooth interior surfaces were secured." (See p. 82.)

In Table 3 are shown average coefficients for observations on the Esopus, Tongore, Foundry Brook, Sprout Brook, Peekskill, Hunters Brook, Turkey Mountain, and Harlem Railroad siphons, for a flow of 350 million gallons per day (542 second-feet). Concerning these observations, made in August of 1915 under the direction of Mr. F. F. Moore, the board of water supply writes:

The condition was not favorable for obtaining the best results on the pipe siphons.
* * * The result of measurements of flow in pipe siphons was recorded as an

¹Engin. Rec., vol. 63, Apr. 15, 1911, p. 404; *id.*, vol. 64, Sept. 16, 1911, p. 332; Eng. News, vol. 66, p. 526; Municipal Jour. and Engineer., Vol. 31, Aug. 23, 1911, p. 229; *id.*, Dec. 7, 1911, p. 719; Jour. N. E. Water-Wks. Assn., Sept., 1911: Waterworks Handbook, by Flynn, Weston, and Bogert, New York, 1916, p. 323.

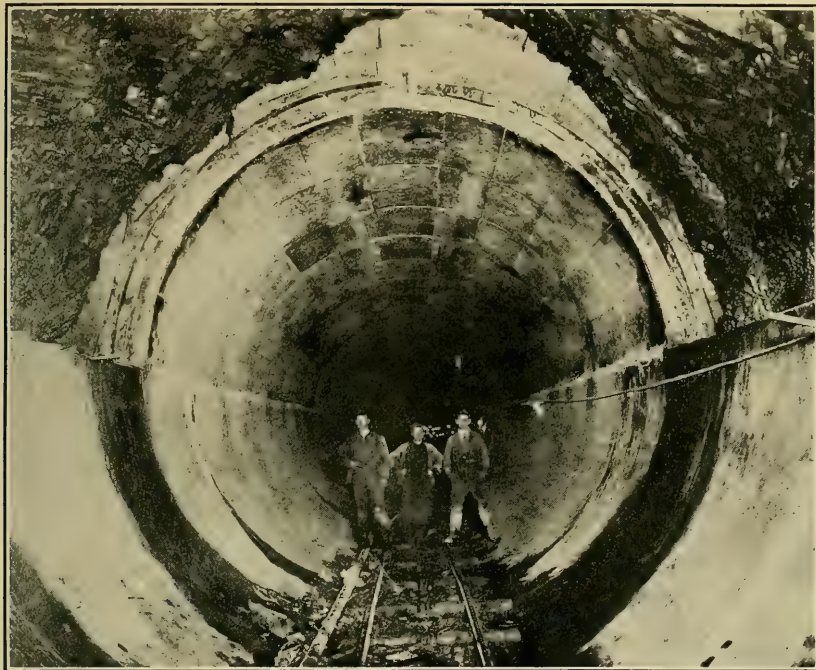


FIG. 1.—RONDOUT TUNNEL, CATSKILL AQUEDUCT.

Typical pressure tunnel construction, showing completed excavation and partial and completed concrete lining.

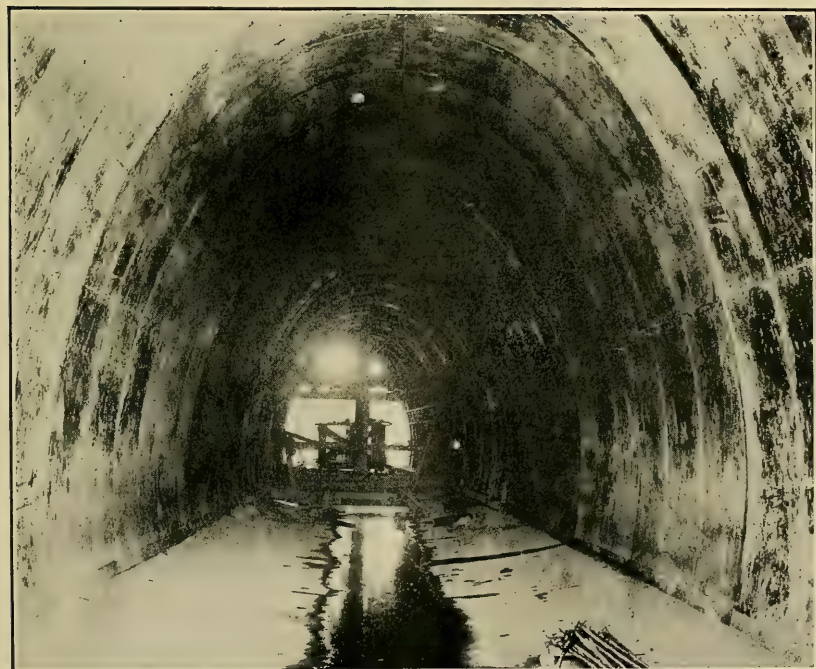


FIG. 2.—CUT-AND-COVER SECTION OF CATSKILL AQUEDUCT, PEEKSKILL DIVISION.

Interior of finished conduit on curve of 3,000 feet radius.

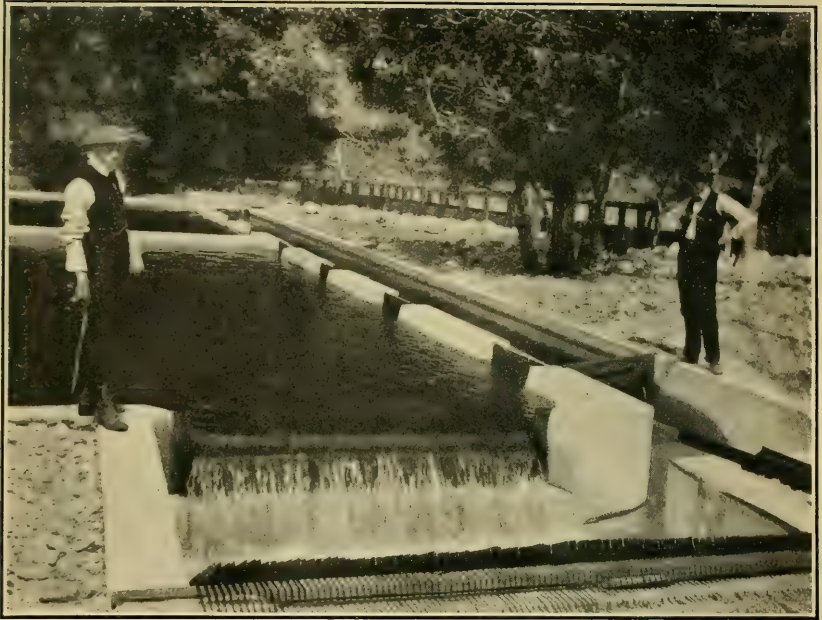


FIG. 1.—WEIR AT INTAKE TO MILL CREEK NO. 3 PIPE LINE, CALIFORNIA.
Used in measuring the water entering pipe No. 51a.



FIG. 2.—INTAKE, LYTLE CREEK POWER PLANT PIPE LINE, CALIFORNIA.
Tapers from 44 inches diameter to 36 inches at pipe line proper. Sand trap shown between open canal and pipe line. (No. 53a.)

average, because observations were not of a character permitting reduction for individual pipes. These pipe measurements included the chamber and transition-section losses, of all kinds, at both ends of each pipe because it was not considered advisable at that time to provide piezometers, or other devices, necessary to the direct measurement of the pipe losses separately. These observations were reduced by taking advantage of the fact that the pipes were of various lengths and the same type of construction, including the chambers, so that the assumption could be reasonably made that the wetted surfaces are practically identical in character: hydraulically, and that chamber losses are the same in all chambers for any given flow conditions. Losses in the pipes were computed, using assumed pipe friction-loss coefficients, which computed pipe losses were subtracted from the measured losses. These computed residual losses were then compared and the set most nearly consistent selected. The coefficient used in obtaining the selected set was assumed to be an average for the several pipes and an approximately correct average because of the method used and the probability that not all pipes were in the same condition as to foulness, hydraulically considered. The value selected is believed to quite closely approximate the truth, because some of the siphon pipes are so short that the total friction loss in them is very small as compared to the chamber losses.

While the observations are not such that definite conclusions therefrom would be warranted, still the indications are that a steel pipe, built up of relatively long sections, well jointed and lined with a smooth cement coating, gives a very efficient surface. Of course the primary object of this coat is to prevent the corrosion of the metal interior but it gives an added satisfaction to know that this prevention has been attained without sacrifice of capacity, for a given sectional area. If anything, the fractional loss is less than it would have been in a new metal pipe and the latter material would have continually lessened in capacity while the lining will probably remain about the same, after the first slime coat is acquired.

No. 39, Experiment M-2.—Rondout pressure tunnel,¹ Catskill Aqueduct, N. Y.—At the Rondout River crossing the Catskill Aqueduct takes the form of a circular pressure tunnel, excavated in solid rock and lined with concrete. From the standpoint of capacity the tunnel is, in essentials, a circular pipe, constructed in place. (See Pl. IX, fig. 1.)

The tunnel consists of vertical downtake and uptake shafts joined by an approximately horizontal tunnel. The developed length of the tunnel is 24,880 feet. About 16,000 feet from the intake a vertical drainage shaft extends from the ground line down to the tunnel. As the ground line at Rondout River is 300 feet below the hydraulic gradient, this shaft is, of course, sealed.

In August, 1915, F. F. Moore, designing engineer of the board of water supply, conducted a series of experiments to determine the friction losses in this tunnel, from the drainage shaft to the outlet, a distance of 9,102 feet. The pressure head at the drainage shaft was measured with a mercury manometer of the pot-and-column type. Mercury readings were corrected for temperature of air and of water in the tunnel. The temperature of the water in the pipes to which the manometers were attached was assumed to be controlled by the ground and therefore unchanging. The mercury column was also read with no flow in the tunnel, thus establishing the levels between gauges.

The elevation of the water surface at the outlet was determined by steel-tape measurements from a bench on the floor over the

¹ Eng. Rec., Mar. 11, vol. 63, 1911, p. 279; Eng. News, June 1, vol. 65, 1911, p. 654; Water Works Handbook, by Flynn, Weston, and Bogert, New York, 1916, p. 284.

uptake shaft. Disturbance was eliminated at this point by passing the flow over stop planks below the shaft.

In the computations it was assumed that the velocity head within the uptake shaft was changed to pressure head without loss. Observations 1 to 4, inclusive, were computed from 31 readings at 5-minute intervals for each observation. For the other observations readings were taken at minute and half-minute intervals for 124 readings. Observations were made about noon on each day, after which the discharge was changed and allowed until the next noon to secure a stable regimen of flow. As stop planks caused a break in the hydraulic gradient immediately below the reach tested, this regimen of flow was quickly attained.

The discharge was measured through a 210-inch Venturi meter located 8 miles above the tunnel. The leakage was known to be small and negligible from tests previously made.

At the time of test the tunnel was new, but had been in operation for sufficient time to allow the surface to become somewhat foul, although the observations were not continued long enough to indicate the probable ultimate deterioration, hydraulically considered, of the surface which long and constant use might bring about.

The concrete lining, 17 inches in thickness, was deposited against clean, oiled steel forms, being carefully spaded near the forms to assure a dense, smooth inner surface. The mixture used was, in general, composed of one part cement to two of sand and four of crushed stone.¹

In conducting the experiments, the discharge (hence the velocity) was reduced from day to day until five observations had been taken. It was then increased from day to day until three more observations had been recorded, the velocities being about the same as those for the first three observations.

A study of Plate VI indicates that for a given loss of head the velocity during the latter end of the series would be about 13 per cent less than that occurring during the beginning of the series.

In reply to a question as to "shoulders" within the tunnels, the board writes:

Regarding "shoulders," by which is understood the irregularities in the concrete surface of waterways occurring at the places where form sections joined, there were such irregularities as commonly occur in the pressure-tunnel linings, but this effect hydraulically is unknown, because of lack of opportunity to compare, under otherwise identical conditions, the measurements as made with results which might be obtained with a smoother lining. The mortar linings of the pipe siphons were unusually free from form irregularities, such as exist being clearly of negligible effect, hydraulically.

No. 40, Experiment M-3.—Wallkill pressure tunnel, Catskill Aqueduct, N. Y.—At the Wallkill River crossing the Catskill Aqueduct takes the form of a circular pressure tunnel, 4.4 miles long, excavated in solid rock with a minimum cover of 150 feet, the tunnel being then lined with concrete. Thus, like the Rondout tunnel, the conduit is a circular pipe, when considered from the standpoint of capacity. (See Pl. IX, fig. 1.)

The concrete was placed as a moderately dry mixture of 1 part cement to 6 parts of aggregate.² Careful spading against the steel

¹ Engin. Rec., Jan. 1, vol. 61, 1910, p. 26; *id.*, Jan. 29, vol. 61, 1910, p. 138; *id.*, Feb. 28, vol. 69, 1914, p. 240; *id.*, Sept. 17, 1910, vol. 62, p. 312.

² Eng. Rec., Apr. 2, vol. 61, 1910, p. 450.

forms, which were well oiled or greased at each set-up, assured a dense, smooth surface.

The equipment and method of taking the observations were the same as those employed in the tests of the Rondout tunnel (p. 81).

It is to be noted from Table 3 that the same discharge, hence the same velocity, held for the observation taken on this tunnel and the Rondout tunnel, for any given day. The tunnels are 5 miles apart, and this one is 18 miles beyond the Venturi meter, where the discharge was determined. (See p. 82.)

When the position and sequence of points is studied on Plate VI the position does not appear to follow a rather definite relationship to the sequence, as was the case for the Rondout tunnel, but the points appear to be indiscriminately placed on either side of the line through the centers of gravity, as is the case with nearly all hydraulic experimentation.

No. 41, Experiment RDJ.—18-foot monolithic concrete-lined tunnel, No. 2 conduit of Ontario Power Co., Niagara Falls, Ontario, Canada.—For the following data concerning some unpublished experiments the writer is indebted to the Hydro-Electric Power Commission of Ontario. These experiments, conducted under the supervision of R. D. Johnston, are of especial importance for two reasons. So far as the writer is aware, the conduit is the largest on this continent, if not in the world. The velocities encountered in commercial operation are three or four times as great as those ordinarily considered as high velocities in long penstocks. The following description is submitted by the commission:

This conduit consists of approximately 6,726 feet of concrete pipe, of which 6,646 feet, located between the gatehouse and surge tank, was tested. Of this 6,646 feet approximately 5,170 feet is straight pipe and 1,475 feet in length is bends to the right of 800 feet radius. These bends consist of short curves separated by short tangents.

The pipe is of oblate shape, approximately 18 feet in diameter, the greatest horizontal dimension being 19.26 feet and the greatest vertical 16.55 feet. The surface of pipe is unusually smooth and even. During construction great care was taken to see that the concrete was carefully spaded next to the oiled steel forms, and after the whole pipe had been erected all defects due to imperfect alignment of forms were removed by chipping and then the whole inside was rubbed down by hand with carborundum bricks. This pipe delivers water by means of a distributor and penstock to 7 turbines developing a total of approximately 91,500 horsepower. The pipe was put in operation in 1910 and the tests were made in 1913 and 1914. An examination of the interior made in April, 1918, showed no signs of cavitation or wear and a total absence of vegetable growth. This latter condition is probably due to the extremely high velocities, which at times reach 28 feet per second. The inside surface is shown on the accompanying photographs taken during the inspection mentioned above. (Pl. XI.)

For the tests the velocity was measured by the "color method." This consists of liberating some coloring substance in the water at a known point and at a given time and recording the time taken for this color to be carried to another known point. The computations were based on an elapsed time, as from the moment of injection to the mean between first and last appearance of the color. The volume of the pipe or other container between the two points is measured or calculated, and this gives the total volume of water which has passed the second point of observation in the recorded time. The velocity of water at any section can then be calculated. In this case the point of introduction of the color was in the mouth of the pipe in the gatehouse and the point of observation was at the tailrace weir opposite No. 7 unit, which is the first one served by this conduit. Adjustments necessary for the change in velocity in the penstock, etc., were made after further tests had been made on the latter. (For a more detailed description of this method see Engineering News of Sept. 23, 1915.)

The loss of head was obtained by observing the water levels at the gatehouse and at the surge tank. The surge-tank riser served as a huge manometer, in which all

small fluctuations were damped, so that close readings were made possible by means of an attached mercury gauge. The difference in level of the water at these two points, which was corrected, in the case of the surge-tank readings, to allow for the velocity head of the water which passed the surge-tank connection, included, of course, the loss at entry to the pipe line. The engineers who made the tests found it impossible on account of the disturbance to measure the pressure of the water in the conduit immediately behind the gatehouse, where the only manhole for a considerable distance is located.

Great care was exercised to obviate errors in observation or calculation.

To obtain the coefficient of the conduit and plot a curve of losses for different velocities of water involved a long series of observations and a large amount of computation. The coloring material used was potassium permanganate in the form of small crystals. It was advisable to use as little of the color as possible and still enough to enable the observer to distinguish it easily at the power-house weir. When the water was clear it required about two-thirds of a pint of crystals. Roily water required considerably more.

The apparent loss of head measured in the conduit is the elevation of water in the forebay minus the elevation of water in the surge tank. There are three corrections to be applied to this resultant figure. It is assumed that the elevation of water in the surge tank is lower than a pitot-tube reading in the conduit opposite the surge tank branch by an amount equal to the velocity head of the water passing the surge-tank branch. Hence this velocity head is added to the level of the water at the gatehouse to give the correct figure for entry loss plus conduit loss, plus distributor loss from gatehouse to surge-tank branch. The entry loss based on the judgment of the engineers and on data impossible to give herein was taken as one-quarter of the velocity head or $\left(\frac{1}{4} \times \frac{V^2}{g}\right)$. The distributor loss from unit No. 7 to the surge-tank branch was obtained by experiment and checked by computation. These two quantities, namely, entry loss and distributor loss, were deducted from the total loss and the net loss in the conduit, due to friction and curves, obtained. By this method about 34 runs were made and computed during the summer of 1913 and 8 more during the summer of 1914. The total range of velocity was from 7 feet per second to 21 feet per second.

The items under No. 41a, in Table 3, are not computed from the 42 runs mentioned in the last paragraph above, but are developed from a velocity-friction loss curve which is itself based on those 42 runs. From this curve the velocities and corresponding friction losses were chosen and the remaining hydraulic elements and the retardation factors in the various formulas computed.

A study of these retardation factors indicates that this conduit is exceptionally smooth. Only in cases where conservation of head is of great value in dollars and cents would the expense of hand treatment, such as is described here, be warranted. If we take the coefficients of retardation at their face value, then this pipe will carry from 10 to 15 per cent more than an average pipe of the type that the writer has classified as of the highest commercial construction. However, it is to be borne in mind that the experiments on this conduit determined gross losses of head from which loss by friction alone must be developed under certain assumptions. While no criticism of the assumptions is made, still the fact remains that, had it been feasible to determine friction losses alone, it is quite possible that the seeming variation of 10 to 15 per cent mentioned above might have been much reduced.

FLOW-LINE PIPES AND CONDUITS.

No. 50, Experiment FF-1.—22-inch jointed concrete pipe of Southern California Edison Co., Mill Creek power plant, No. 2, California.—The description of the experiment upon this line, as taken from correspondence with Mr. Finkle reads:

The pipe was made in 2-foot sections in the ordinary plain cement-pipe forms as used for that purpose, and consisted of 1 part Portland cement and 3 parts sand mixed



FIG. 1.—INTERIOR, CONDUIT NO. 2, ONTARIO POWER CO., NIAGARA FALLS, ONTARIO.

Note from text that form scars were chipped down; then whole surface rubbed down with carborundum bricks.

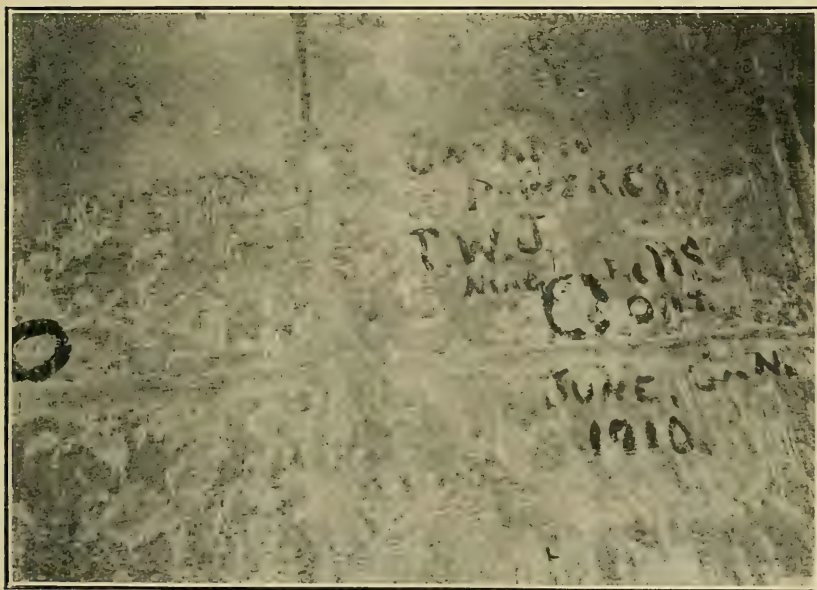


FIG. 2.—MINIMUM OF EROSION BY CLEAR WATER.

After eight years' service the conduit shown in figure 1 has not been eroded sufficiently to obliterate paint marks made on walls in 1910. As velocities reach 28 feet per second, this is remarkable evidence that good concrete does not erode under sliding contact with clear water. This view taken March 31, 1918.

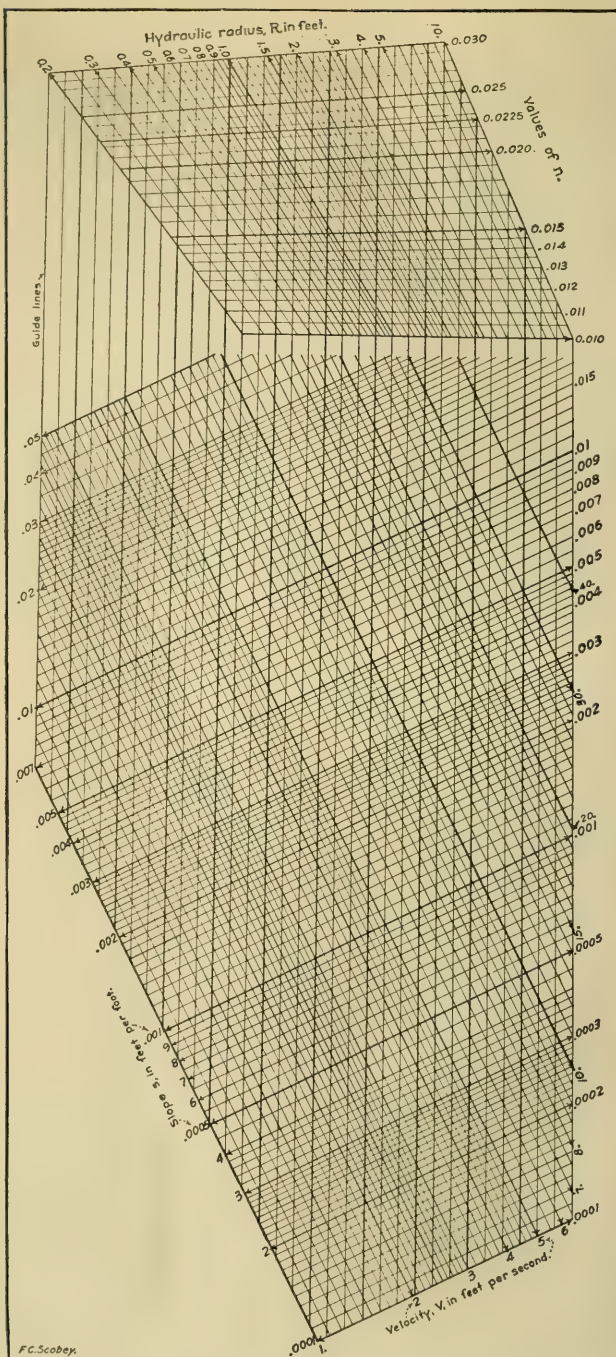


DIAGRAM FOR THE SOLUTION OF GENERAL PROBLEMS INVOLVING THE KUTTER FORMULA.

From the intersection of R and n follow the guide lines to the intersection of S and V , or from the intersection of S and V follow the guide lines to the intersection of R and n . For circular pipes remember that $D=4 R$.

with fine gravel not exceeding 1 inch in diameter. The sections were joined together in the ordinary way with cement mortar mixed with 1 part cement to 2 parts fine sand. The line has tangents ranging in length from about 100 feet to 500 or 600 feet, and curves, none of which have a less radius than 15 feet. The slope was made uniform at the rate of 10.56 feet per mile.

This pipe line delivered at its lower end, when filled to its full capacity, 9.2 second-feet without any pressure at the intake, which was provided with an enlarged section for accelerating the flow of water in the pipe. It was observed that the pipe did not run full below the first 2,000 feet. Subsequently the upper 100 feet of the pipe were raised to accelerate the water a little more, after which numerous tests were made to determine the greatest volume of water that could be passed through the pipe. From this I found that the pipe would carry the most water when filled within 1 inch of the top, or when carrying a depth of 21 inches of water. Under this condition the pipe delivered 9.8 second-feet of water. The discharge of the pipe was measured by means of a rectangular, fully contracted Francis type of weir in one-eighth inch steel plate, and head taken with hook gauge. The depth of water in the pipe, from which the velocity and hydraulic radius are computed, was measured by means of a straightedge and hook gauge at the manholes, which are located every 500 feet along the line. Instead of using a trowel to make the joints, as is ordinarily done, I made a brass band ring 10 inches wide, having spokes equipped with turnbuckles on the inside to vary its diameters, the ring being flexible and lapped to permit reducing or enlarging its circumference.

In making the joints the pipes were carefully laid and evenly joined, and mortar applied in the groove all around. Then the brass ring, reduced in diameter to slip into place, was introduced and centered over the joint. By working the turnbuckles the ring was then expanded to fit the diameter of the pipe and its inside circumference, thus squeezing the mortar into the crack and the surplus out to the edges of the ring.

Grasping the spokes, the ring was then turned around slowly about five times to give the joint a smooth surface, after which it was loosened and removed, and all surplus mortar removed with a trowel, in such a manner as not to mar the surface left by the ring.

This method made the joint smoother than any other portion of the pipe, and, so far as the eye could detect, made the pipe continuous on the inside. Had the same method been used for the 31-inch pipe for Mill Creek No. 3 line (No. 51) and for the 36-inch pipe for Lytle Creek (No. 53) I have no doubt these would have given about the same value for n in Kutter's formula.

The nominal slope was used in computation.

As shown in Table 11 the above test indicates the value of n to be about 0.0116 for this pipe. If truly representing the inner surface of the pipe, the joints were most carefully made and the pipe in excellent condition. (See discussion No. 51 following.)

No. 51, Experiment FF-2.—31-inch jointed cement pipe of Southern California Edison Co. Mill Creek power plant, No. 3, California.—The description of the experiment upon this line, as taken from correspondence with Mr. Finkle, reads:

The diameter of this pipe was 31 inches and it was given a slope of 10.56 feet per mile. Its length was between 5 and 6 miles, with a few interruptions in the line, where steel siphons were used to cross ravines. Having profited by my experience regarding accelerations at the intake, showing that the pipe would be full at the upper end and only partly filled at the lower end, I gave this line additional fall in its upper part, calculated by a formula for that purpose.

This pipe was manufactured in the same way as the 22-inch pipe (No. 50, p. 84), except that 1 part of cement was used and 4 parts of sand, containing considerable gravel, the largest of which was $1\frac{1}{2}$ inches in diameter. It was made in 2-foot sections, and laid in the same manner as the 22-inch pipe. The result was that the maximum capacity of the pipe occurred when it was filled to within $1\frac{1}{2}$ inches of the top or when it only carried a depth of water of 29 $\frac{1}{2}$ inches. The carrying capacity of the pipe under these conditions was 19.72 second-feet.

This line was laid in 1901 and tested the same year. There are numerous curves between the tangents of various lengths, but none of the curves has a radius of less than 20 feet. The discharge was determined by using a Francis type rectangular, fully contracted weir in three-sixteenths-inch steel plate, measuring head with a hook gauge. (See Pl. X, fig. 1.)

The depths of water in the pipe, from which the velocity and hydraulic radius are computed, were measured by placing straightedge along inside of upper invert on

each side of manholes and using hook gauge from top of straightedge down to surface of water.

The nominal slope of the pipe was taken in the computations of the retardation factors for the various formulas. As shown in Table 11, page 68, this experiment indicates a value of n in the Kutter formula of 0.0142, and so far as can be determined from the descriptions of this pipe and the 22-inch pipe the values are accounted for by the manner of making the joints. (See discussion No. 50 above.)

No. 53, Experiment FF-3.—36-inch jointed cement pipe of Southern California Edison Co., Lytle power plant, California.—The description of the experiments upon this line, as taken from correspondence with Mr. Finkle, reads:

This 36-inch line, laid in 1904, was given a slope of 5.28 feet per mile, and allowance made for acceleration of the water at the intake (as explained for pipes Nos. 50 and 51, which see also for manufacture of pipes). The pipe showed a delivery of water amounting to 20.06 second-feet, when running within $1\frac{1}{2}$ inches of the top, or with a depth of water equal to $34\frac{1}{2}$ inches in the pipe.

In the year 1908 a second test showed the capacity had increased, so as to deliver 21.2 second-feet under the same conditions as it previously delivered 20.06 second-feet. Investigation showed that this was due to a fine deposit of carbonate of lime formed on the interior of the pipe, almost making a glazed surface over the cement. This was deposited by the water of Lytle Creek, which contains considerable lime carried in the water in the form of bicarbonate.

This line contains numerous curves between tangents of various lengths, but none of the curves has a radius less than 34 feet.

The discharge was determined by passing water over a rectangular, fully contracted Francis-type weir in three-sixteenths-inch steel plate, and depth was observed with a hook gauge. The immediate intake was tapered from 44 to 36 inches in diameter (see Pl. X, fig. 2). The depths of water in the pipe, from which the velocity and hydraulic radius are computed, were measured by holding a straightedge against the upper invert on each side of the manholes and measuring from the top of straightedge in manholes to the surface of the water.

The nominal slope of the pipe was taken in computing the retardation factors for the various formulas. According to the experiments, the glazing action of the lime improved the value of n from 0.0145 when the pipe was new to 0.0138 when it was 4 years old. Experiments at the end of, say, 10 years might show a very efficient surface but a decrease in capacity, due to throttling of the water section, assuming the deposition of lime to continue.

No. 54, Experiment Ehle-1—Victoria Aqueduct, Vancouver Island, British Columbia, Canada.—Water was first turned into this pipe line on May 14, 1915 (see Nos. 30 and 31). On May 23 and 24, 1915, Boyd Ehle conducted a series of tests to determine the friction factor n in the Kutter formula.¹ As shown in Table 11, p. 68, the range of these tests extended from 3.36 second-feet flowing with a depth of but $8\frac{5}{8}$ inches up to 40.59 second-feet which filled the pipe, thus extending through the transition from an open channel (i. e., with water surface exposed to the air) to a pipe running full of water. It is not often that an installation is such that the behavior of water may be studied through this transition, as a pressure pipe is full of water, whatever the discharge, and a flow-line pipe as a rule is protected against complete filling by spillways near the upper end of the line.

The reach covered by this series was 800 feet long. The upper end is near the pipe-line intake at Sooke Lake. The discharge was measured over an 8.02-foot sharp-crested rectangular weir, corrected

¹ Engin. Rec., Oct. 2, 1915, vol. 72, p. 409.

for velocity of approach. The depth of water upstream from the weir crest was 3.40 feet and the end contractions 1.50 feet and 1.55 feet, respectively. For all discharges less than 17.0 second-feet, the bottom and end contractions were in excess of two times the head on the weir. For greater discharges than the above, the end contractions are not sufficient to give standard conditions. The mean velocity for any particular run of water was taken as the discharge divided by the mean of the areas of the water sections at the two ends of the reach. The slope was taken as the constructed slope of the pipe line, a fall of 1 foot per 1,000 feet of pipe.¹

The reach tested consisted of about equal amounts of tangent and curve, as is typical of this line, but did not include any of the siphon pipes. There is so much curvature on this line (50 per cent) and the individual curves are as a rule so sharp that the values of the coefficients of retardation may be taken as for a very smooth pipe with an excess of curvature. In other words, the average pipe with the same type of construction would probably show even more favorable carrying qualities.

No. 55, Experiment Ehle-2.—42-inch reinforced concrete flow line, Victoria Aqueduct, Vancouver Island, British Columbia, Canada.—With the following modifications the same discussion applies to this reach as to No. 54 above:

After flowing for 27 miles through a flow-line pipe, except for six inverted siphons, laid on a uniform grade of 1 foot fall per 1,000 feet of pipe, the water wells up through 110 holes 4 inches square from an outlet chamber just upstream from an 8.04-foot weir similar in construction to the one at the intake, except that the depth from the perforated floor to the crest of the weir is 1.88 feet and the end contractions are 5.5 feet each. For all observations the end contractions were more than twice the head on the weir; but the bottom contraction did not conform to standard conditions for a discharge greater than 17 second-feet.

This series of observations was made on a reach of pipe about 800 feet long, just upstream from the weir described above where the discharge was measured.

No. 58, Experiment JBL-1.—Tunnel No. 15, San Gabriel plant, Pacific Light & Power Co., California.—Just before starting the construction of the Los Angeles Aqueduct a series of experiments was made on both open and covered concrete channels, located in southern California. The measurements, made by Charles H. Lee and D. L. Reaburn, were reported by J. B. Lippincott² under whose direction the experiments were conducted. (See p. 11 for Mr. Lippincott's conclusions.) Of this tunnel he writes:

The section is rectangular, $4\frac{1}{2}$ feet wide and 4 feet deep, with a semicircular arch, and finished with a 1 to 3 cement-mortar plaster.

There was no vegetable growth in the tunnel which could be felt or seen. The tunnel has been in use for eight years. There is a slight curve at the upper portal. Discharge measurement was made on tangent above the curve. Twenty feet beyond lower portal there was a sharp angle in alignment.

¹ In the opinion of the writer the slope should have been taken as the fall of the surface of the water in the pipe, corrected for changes in the velocity head due to changes in the areas of the water sections at the two ends of the reach. However, his own experience on this same pipe indicates that practically the constructed value for the slope is obtained when determined by the surface fall with the above corrections. (See column 13, Table 11, opposite pipe No. 56.)

² Observations to determine the value of C and n as used in the Kutter formula by J. B. Lippincott, *Engin. News*, June 6, 1907, vol. 57, p. 612.

The discharge was measured with a current meter. Depths were determined from a horizontal straightedge. On account of rough topography, floor elevations as furnished by the company were accepted in computing the slope of the water surface. The value of n was found to be 0.0127. (See p. 11 for Mr. Lippincott's conclusions.)

No. 59, Experiment JBL-2.—Tunnel No. 23 of the same system as above.—Of this experiment Mr. Lippincott writes:¹

This test was made at tunnel No. 23 of the same system. Conditions were similar in all respects, except for slight curves just below north portal and above south portal. The length of tunnel is 318 feet and grade of floor 0.00095 foot per foot; n here was 0.0115.

(See p. 11 for Mr. Lippincott's conclusions.)

No. 60, Experiments JBL-5 and 6.—Main supply conduit for Los Angeles, Calif.—These tests are described as follows:

These were on the main supply conduit for Los Angeles, near the old ostrich farm, several miles north of Los Angeles. It is covered and has been in use four years. The length of section was 700 feet, being between two manholes. A curve occurred on this section. The wetted perimeter was very smooth, apparently of a 1 to 3 cement mortar. There was no sand, moss, or vegetable growth of any kind. Experiment 5 was at the upper and 6 at the lower manhole. The grade of the floor was the same as that of the water surface. The surface was a cement plaster on concrete. The value of n here was 0.0112 and 0.0109. (See p. 11.)

No. 61, Experiment AFB-1.—Loch Katrine Aqueduct, Glasgow, Scotland.—The concrete-lined portion of the new aqueduct from Loch Katrine to Glasgow was tested in 1895 by A. F. Bruce.² Of the construction he writes:

Open frames of 6-inch by 2-inch battens were first placed in position and three-fourth-inch tongued and grooved boards, smeared with soft soap, nailed to the frames horizontally as the concrete was filled in. Every possible precaution was taken by working with spades to obtain a good face, and except where some defects showed themselves, no redressing was afterwards necessary.

About 53 per cent of the aqueduct was lined. The section units were from 12 to 15 feet long, generally 12 feet. The reach tested was straight. The quantity of water was measured over a weir. The depths of water in the aqueduct were read on gauge rods in the chambers. Water at the lower end was checked by the fact that one siphon gate below the reach under test was closed.

The lined section is 9 feet 1 inch wide on the bottom, with the invert dished 6 inches. The sides batter until at the spring line the width is 10 feet. The rise of the arch is 3 feet. Depth over all is 9 feet.

Most of the observations indicate a correct value of n for this new channel of about 0.0124.

No. 62, Experiment P-1.—Aqueduct of the Serrino, Naples, Italy.—In 1896 Perrone wrote³ of a test made on the aqueduct of the Serrino, at Naples, Italy. This channel, of pure cement, polished, had vertical sides and elliptical bottom. The discharge was measured with a current meter. The value of n , being but 0.0107, indicates the workmanship and lack of slime to be all that the short description implies.

¹ Observations to determine the value of C and n as used in the Kutter formula by J. B. Lippincott, Engin. News, June 6, 1907, vol. 57, p. 612.

² Observation on the Flow of Water in the New Aqueduct from Loch Katrine; Glasgow Corporation Waterworks, A. F. Bruce, Paper No. 2921, Pro. Inst. Civil Engineers, Vol. CXXIII, 1895-96, part 1, p. 410.

³ Zoppi, Sul Volturno, Carte Hydrographique d'Italia; The Flow of Water, by Louis Schmeer, New York 1909, pp. 46, 80, 93.

No. 63, Experiment F-S.—Sudbury Aqueduct, Metropolitan water works, Boston, Mass.—Alphonse Fteley and F. P. Stearns conducted a series of experiments upon the Sudbury Aqueduct in 1880.¹ The conduit was new, of horseshoe shape, 9 feet wide and 7.7 feet high. The discharge was measured over a weir. This aqueduct contained sections lined with brick alone, and also sections lined with a coating of cement mortar over the brick. After stating that the capacity of the brick section is represented by the formula $V=127R^{0.62}s^{0.5}$, they add:

When the inside of the conduit is lined with a coating of mortar made of fine Portland cement, its flowing capacity is from 7 to 8 per cent greater. This coating, though applied with floats, did not present as smooth a surface as was obtained in other portions of the conduit, where experiments would probably have given higher results. In some parts of the conduit where the brick surface was covered with a wash of Portland cement laid with a brush, the flowing capacity was increased to the extent of from 1 to 3 per cent.

Note that the exponents in the above formula are the same as those adopted by the writer. Also see discussion by Mr. Hazen on page 97. For the cement-lined section their formula would have read $V=137R^{0.62}s^{0.5}$, which becomes, in terms used by the writer (see p. 49), $V=0.394d^{70.62}H^{0.5}$, indicating a capacity about 6 per cent greater than the formula for the best grade of construction as suggested by the writer.

Nos. 65, 66, and 67, Experiment H.—108-inch cement-washed brick sewer, North Metropolitan sewerage system, Boston, Mass.²—Theodore Horton describes experiments conducted upon a 9-foot circular brick sewer, the interior of which had been washed with cement mortar. So far as carrying capacity is concerned, the pipe is of cement. Extending over a period of several years, these tests show what may be expected with the lapse of time, when sewage is conveyed in a concrete or cement lined channel. Below the East Boston pumping station the cross section of the sewer is a 9-foot circle for 2,000 feet; thence a horseshoe shape of the same area as the circle for 2,000 feet; thence another 9-foot circle for an additional 3,000 feet. A uniform gradient of 1 foot fall in 3,000 feet is maintained. The exact length of reach tested is not disclosed, but the statement is made that simultaneous measurements of depth showed the flow line above the horseshoe cross section to be parallel to the invert. Thus the nominal grade of the line might be accepted without correction for any change in the velocity due to nonparallel flow. The discharge was determined with carefully conducted current-meter gaugings and the cross section by actual measurement. The first series was made in 1896, 10 months after the system at this point had been put in operation. The next series was made in 1897, after these channels had been in operation about 26 months, during which time ample opportunities for changes in the carrying capacity had taken place.

The third series was made in 1900. The sides of the sewer, above and below the average water line, were covered with a thin coating of grease of a leaden color, and supported an organic growth, probably of a fungus nature. By this time there were slight incrustations at frequent intervals, due to barely visible seepage of ground water, and the growth, while not much heavier, covered a greater

¹ Trans. Amer. Soc. Civil. Engin., vol. 12, p. 17. See also Jour. Assoc. Eng. Soc's. vol. 26, p. 163.

² Trans. Amer. Soc. Civ. Eng., 46 (1901), p. 78.

area on the sides of the sewer. The incrustation seemed slightly heavier, but the organic growth did not show any marked increase over that at the time of the 1897 tests.

In his discussion Mr. Horton accepts the value of n of 0.0117 for 1896, of 0.0127 for 1897, and of 0.0133 for 1900. (See Table 11, p. 69 for individual values of each observation.) He notes that the deposits of grease and of organic matter were greatest on the sides, especially near the line of average flow; that the bottom was clean scoured by sand and other heavy particles.

In his discussion on these experiments, Rudolph Hering mentions several cases where the deposit exceeded that noted by Horton. Mr. G. C. Whipple brings out the point that the organisms which grow in sewers are vegetable forms of a very low type, while those found in water pipes belong to the animal kingdom—fresh-water sponges, etc.

The results of these tests would indicate that sewage undoubtedly coats a cement surface to such an extent that an exceptionally smooth interior surface would not long contribute to a high capacity, as would be the case for most clear waters. By the same deposits, on the other hand, a very rough interior might be so smoothed over that the capacity will be increased, provided the sewage was sufficiently diluted with surface or other ordinary waters, thus preventing excessive deposits.

Nos. 68, 69, and 70, Experiment H-2.—Basket-handle cement-washed brick sewer, North Metropolitan sewerage system, Boston, Mass.—Simultaneously with the tests described as Nos. 65, 66, and 67, Horton also made experiments upon the basket-handle section adjoining the circular section. The shape was 6 feet by $6\frac{3}{4}$ feet, but otherwise similar in construction to the circular section. The general description under the latter applies also to this section.

The difference in the values of n for the two shapes would indicate that a better surface is obtained in a circular form than upon plane faces, or those requiring hand troweling. A review of tests for carrying capacity shows this fact to be quite general.

No. 71, Experiment M-4.—Cut-and-cover sections of the Esopus division, Catskill Aqueduct, New York State.—Long reaches of the Catskill Aqueduct were constructed as flow-line sections, as distinguished from the reaches under pressure.¹ These sections are of the cut-and-cover type, a concrete horseshoe $17\frac{1}{2}$ feet wide and 17 feet high.

The invert, 16 inches thick, was laid first, in alternate panels each 15 feet long. After the forms had been filled—

The work is screeded with a 16-foot length of 3-inch circular steel shafting, which is rolled along the top of the forms, bearing on the web plates and the horizontal legs of the angle irons riveted to them. Great care is taken to obtain a smooth finished surface.

For the walls and arch, steel forms in 5-foot units bolted into 15-foot sections were used. From invert to arch any one section was completed at one pouring. After the oiled forms were in position, four men crawled between the forms, two on each side. As the concrete, a wet mix in a ratio of about 1 to 3 to 5, was poured in

¹ Engin Rec. vol. 61 Jan. 8, 1910; vol. 62, Nov. 5, 1910; Water Works Handbook, Flinn, Weston and Bogert, New York, 1916, p. 271.

from the top, these men spaded it away from the inside form, so that the inner surface of the conduit is very smooth. (See Pl. IX, fig. 2.)

Simultaneously with the hydraulic experiments upon the tunnels and cement-lined pressure pipes described on pages 80 to 83, inclusive, measurements were made on three reaches of the cut-and-cover flow lines. For nearly half the runs nonparallel flow was indicated. That is to say, the slope of the water surface was either greater or less than the slope of the invert. The computations were not completed for such runs, but for all runs where the flow was uniform the hydraulic elements are given in Table 11, page 70. The quantity was measured by Venturi meter, as described for the pressure conduits. The areas and wetted perimeters of the water sections were determined by measurements from arch intrados to water surface.

The velocities were computed from the continuity equation $V = \frac{Q}{A}$.

The coefficients of retardation indicate that quite high efficiencies are perfectly feasible in conduits of great size if care is taken to work the concrete mix into close contact with smooth forms and if care is exercised in moving the forms so that no offsets or shoulders are developed. A glance at the items in Table 11, page 70, shows the same indication toward incipient fouling that was found in the experiments on the pressure tunnels and pipes. The sequence of tests is shown by the order of observation numbers. For any given reach of conduit the retardation factors indicate a rougher surface from day to day when the water is first turned into a conduit.

DISCUSSION OF "FLOW OF WATER IN CONCRETE PIPE."¹

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DISCUSSION BY MR. ALLEN.

It is fortunate that in these times of soaring prices for cast-iron pipe a competing material for many purposes is found in reinforced concrete, for a careful perusal of the author's important and exhaustive investigation demonstrates that if we can be sure of the best material and fabrication, this material can be safely used—at least under reasonable head—and with economy.

In estimates for a 48-inch force main 12,350 feet long, based upon prices ruling in the summer of 1916, there was found a saving of \$84,000 by the adoption of precast concrete pipe instead of cast iron, or 44 per cent of the cost for the latter. The difference to-day (Feb. 16, 1918) would be still greater.

Precast concrete pipe appears to be particularly well adapted to sewer construction for several reasons: Joints are infrequent and consequently infiltration should be small; the width of trench is a minimum, causing less inconvenience to traffic and reducing the excavation; there will be little danger from corrosion due to acids sometimes observed with cast iron when used for sewers; and, finally, instead of a marked decrease in carrying capacity, due to tubercles, it would appear that the excellent surface obtained when first laid is subject to little deterioration from time. This means that for the same ultimate capacity we may assume no larger diameters and gradients, and possibly less, than for cast iron—certainly less than would be justified with ordinary brickwork or mass concrete. Therefore the best precast pipe would seem particularly adapted to the construction of those sewers where, on account of the flat topography or in order to reach the outlet at the desired elevation without pumping, minimum gradients must be employed.

With a sewer 4 feet in diameter, for instance, and with a minimum velocity when flowing full of $2\frac{1}{2}$ feet per second, the frictional loss per mile will be with—

New cast-iron pipe = 2.11 feet (Williams and Hazen formula $C_w = 130$).

Old cast-iron pipe = 5.17 feet (Williams and Hazen formula $C_w = 80$).

Ordinary mass concrete = 2.72 feet (author's formula $C_s = 0.31$).

Best precast concrete = 1.91 feet (author's formula $C_s = 0.37$).

In other words, under the conditions assumed, the friction loss with cast-iron pipe will vary from 1.1 to 2.7 and with ordinary concrete work will amount to 1.4 times that to be had with the best precast concrete pipe.

With any concrete pipe subjected to pressure, as in the case of slabs, bins, or concrete ships, reliance must be placed on the excellence

¹ The original manuscript of the preceding paper was submitted to the men named, who in their varied experiences are familiar with concrete pipes for the conveyance of water for irrigation, power, and municipal use, and also for the conveyance of sewage. Criticism and discussion of the manuscript were asked for. Acknowledgment is now made of the time and labor expended gratuitously in preparing the discussion and comments given here. Throughout the discussion "the writer" will refer to the name heading that particular part of the discussion and "the author" will refer to the author of the paper.

of the material and workmanship entering into the structure. Thorough inspection is quite as important as careful design and well-drawn specifications to avoid the possibility of failure.

DISCUSSION BY MR. BENT.

The author has reached a conclusion that in an empirical and ignorant way I reached many years ago. Our own struggle in laying concrete pipe lines has been, as the result of these conclusions, to secure the greatest possible smoothness of joints. I think we began to realize the importance of this shortly before we built the 12-mile line in Boulder Canyon, which the author has mentioned, and it was very interesting to learn that after these years of service he found the line carrying the quantity of water for which it was figured. At the time we were laying it, the Central Colorado Power Co.'s engineers were in a very anxious state of mind because some one had accidentally used a lower value for n than the chiefs later on approved, but it was then too late to change the diameter of the pipe. It was freely predicted that there would be bitter disappointment in the amount of water delivered. We tried to have the disappointment on the right side and succeeded by care in the work.

The entire line was laid by us under contract and the joints inside and outside were made of 1:2 mortar put on solely with a trowel.

I used to talk about 0.012 being perfectly safe for n and 0.011 as being perfectly attainable. I still believe this was right, but it is so difficult to control field conditions that for some time we have pushed these values up one figure, and that seems to be about the conclusion the author has reached.

DISCUSSION BY MR. FINKLE.

From experience with the manufacture of concrete pipe and its use, the writer has come to the conclusion that the carrying capacity of such a pipe is almost entirely in the hands of the engineer having charge of its design and construction. This statement relates more to the ordinary gravity-flow concrete pipes made in 2-foot sections and joined in the trench, but it will also apply in a considerable degree to other classes of concrete and cement pipes.

Three points are important in attaining a high carrying capacity of concrete pipes. These may be briefly stated as follows:

First, use as wet a mixture as possible and thoroughly settle the concrete in the forms, making every effort to have gravel and crushed rock in the mixture covered by a film of the fine sand and cement mixture on the inside of the pipe. This object can be attained by using more forms, so the sections can remain longer in the forms and a wetter mixture can be employed. The increased cost of this will be slight, as it will only be the interest on investment and wear and tear of the additional forms.

Second, in laying the pipes the joints must be carefully made so that there will be no projections or rough places where the sections are united. This can be accomplished by using the revolving brass band described in connection with the author's No. 50, experiment FF 1.

Third, careful attention must be paid to the alignment and grade on which the pipe is laid. This is important, as it eliminates irregularities in flow due to uneven bottoms and angles or irregularities.

The writer's experience has been that curves should have a radius of not less than six times the diameter of the pipe.

If these precautions are taken there is no reason why concrete pipes can not be so produced as to have a value of $n=0.011$, or even 0.0105 in Kutter's formula. It is therefore principally a question of engineering, which I am sorry to say has been grossly neglected in connection with concrete pipe work in the past.

Little light can be thrown on the possible carrying capacity of concrete pipes by studying most of the old pipes of this class found in southern California, as they were nearly all laid out without any engineering supervision, or a proper survey to give uniform grade and proper alignment. A review of the author's experiments on these old pipes clearly prove this point.

In practice, the carrying capacity of concrete pipes, in common with other kinds, is often greatly reduced by the entrance of air at the intake. It is often customary to take the water into a pipe line from the overfall of a Francis weir for measuring it. The effect of this is to cause a large volume of air to be carried into the pipe with the water. The writer has often found this condition in connection with concrete pipes in southern California and elsewhere, and, after correcting it, has increased the carrying capacity of the line from 10 to 20 per cent.

The examples of concrete pipe given by the author, with which the writer was connected, are the 36-inch Boulder Creek concrete pipe line in Colorado, designated No. 52, experiment S 41, for which work he prepared the specifications and acted as consulting engineer. The experiment from which the author obtains a value of $n=0.012$ was near the upper end of this pipe. If the test had been made at a point farther down the line it is probable that a value of $n=0.0116$, or better, would have been obtained, the same as for the Mill Creek No. 2 pipe (No. 50, experiment FF 1), because the two pipes were manufactured and laid in the same summer.

It has been well demonstrated as a hydraulic principle that there is a slight but constant acceleration of the velocity in long gravity-flow pipe lines of this kind, and the writer has found a difference in the value of n near the upper and lower ends of such pipes, where all the conditions were exactly alike. This phenomenon has been referred to by some authorities and called by the name "Constant acceleration in gravity conduits."

Both the Boulder pipe (No. 52, experiment S 41) and the Mill Creek No. 2 pipe (No. 50, experiment FF 1) were made and laid by day work under careful engineering supervision, which explains the results obtained as to carrying capacity, although these pipes were both made in 2-foot sections by the dry-mix process. It is the opinion of the writer that, had these pipes been made with wet mix, they would have showed a value of $n=0.0105$, or probably even a little better.

As to the other two pipes, for which the writer was engineer, namely Mill Creek No. 3 (No. 51, experiment FF 2) and Lytle Creek (No. 53, experiment FF 3), it must be remembered that both of these were installed by contract and without proper precautions in regard to making the joints, which is wholly responsible for the higher value of n and less carrying capacity of these pipes.

From the above and from all other experiences of the writer, his conclusion is that the values of n given by the author, as applicable to the best constructed pipes, which can be produced by the dry-mix

method, are as stated by the author, namely, for from 12 to 24 inch pipes $n=0.011$; from 26 to 48 inch pipe $n=0.0115$; and for pipes over 50 inches in diameter $n=0.012$.

On the other hand, pipes made with a wet mix and laid with equal care by using the brass-band device, or some other method for making the joints smooth, should show better results, probably about as follows:

For pipes 12 to 24 inches in diameter, $n=0.010$ to $n=0.0105$.

For pipes 26 to 48 inches in diameter, $n=0.0105$ to $n=0.011$.

For pipes over 50 inches in diameter, $n=0.011$ to $n=0.0115$.

In reference to the decrease of carrying capacity in concrete pipes, after they are laid, the writer has formed the following opinions from his own personal observations:

First. There is no risk of interfering with the carrying capacity of concrete pipes on account of roots entering them if they are properly made and laid. There is no case of record where roots have entered cement pipes, unless they were made without being properly tamped, or the spaces in making field joints were not properly filled with mortar.

In this respect concrete pipes are different from vitrified-clay pipes, from which it is very difficult to exclude the roots of certain trees. This difference is due to the fact that it is not easy to cause proper adhesion between cement mortar and vitrified clay, when making field joints, while perfect adhesion between a concrete pipe section and the mortar used for making joints can always be had, so as to eliminate all possibility of roots entering at the joints.

Second. Some concrete pipes have become deteriorated through scour, the surface having become pitted and rough. Several cases of this kind have been observed by the writer in southern California.

Such instances, however, are due to one of two things, either on account of too little cement in the concrete from which the pipes were made, or subjecting properly made pipes to unreasonable water velocities, particularly when the water carries sand or silt. Proper engineering will prevent anything of this kind, as every case where it has been done is an instance of design and construction without proper engineering advice.

Third. It is possible, under many conditions, to have accretions occur on the interior of concrete pipes, whereby their capacity will be decreased. The most frequent cause of this is the deposition of mineral carried by the water in solution, either in its pure form or combined with silt and sand, carried by the water in suspension.

As shown by the author, the most common mineral causing deposition on the interior of concrete pipes in southern California is bicarbonate of lime, and this will apply equally to any other locality where waters contain bicarbonate of lime in solution. Unless the water is very heavily impregnated with bicarbonate of lime and the velocity in the pipe is rapid, the deposition is very slow and would require a long time to make much change in the capacity of a pipe line, unless the water also carries such matter as silt, sand, and fine gravel in suspension.

The writer has observed that the deposition of bicarbonate of lime is much more rapid from water which is warm than from cold water. This observation was made in connection with steel and iron pipes in the domestic water system in the city of Rialto, San Bernardino County, Calif., which carried water from Lytle Creek. Attention was

first called to the matter about 10 years ago, when it was discovered that a film of bicarbonate of lime had been deposited on the interior of the 36-inch concrete pipe line (No. 53, experiment FF 3) referred to in the author's treatise.

The writer then made an examination of the steel and iron pipes in the domestic water system at Rialto, carrying the same kind of water, and found these pipes coated in the same manner as the concrete pipe, the thickness of the accretion depending upon the length of time during which the pipe had been in service.

Some of these iron and steel pipes had been laid since the year 1885, and during the 20 years of their use had accumulated from one-fourth to three-eighths of an inch coating on the inside. After that two experimental steel pipes were installed for observing the effect of water. One of these was placed in position in the month of November, and when observed again the following April there was very little evidence of any deposit. At the same time, another pipe section was installed new, just below the one which had been in use from November to April, and an observation was made on each the following October, which showed that both of them had become thinly coated with a deposit resulting from bicarbonate of lime in the water. As the only difference in the conditions was the temperature of the water, which was cold during the winter and warm during the summer, the conclusions were that the warmer the water the more rapid would be the deposit in the pipe.

Another instance of deposit from water carrying bicarbonate of lime in solution on the interior of a steel pipe was observed by the writer in connection with a 36-inch steel siphon carrying the waters from the Southern California Edison Co.'s Lytle Creek power plant from the tailrace of the plant across the canyon to the intake of the Fontana Development Co.'s canal. In 1916 the floods washed out a small section of this pipe, revealing the broken ends of the pipe still in place. On the interior was a deposit of about one-eighth of an inch in thickness over the asphaltum coating.

This pipe line was a steel riveted pipe, dipped in asphaltum according to the practice in southern California, and was installed new by the writer in the summer of 1904, and had therefore been in use for over a period of 11 years, when it was broken by the floods and observed. The deposit seemed to form over the asphaltum in exactly the same manner as it had been observed to form over the bare steel and iron surfaces in some of the pipes in the Rialto domestic water system.

The conclusion from all of the above is that deposits from water impregnated with mineral will form on the interior of any kind of a pipe, and that concrete pipes have no greater affinity in attracting such deposits than other classes of pipe.

DISCUSSION BY MR. HAZEN.

The author deserves a great deal of credit for making a large number of useful tests of the frictional resistance of water in concrete pipes. These pipes are now used to an important extent, and they are sure to find increasing application. There is a great diversity in the methods of making concrete and cement pipes, and it is not surprising to find from the tests that the coefficients vary through a wide range.

It may be suggested that the coefficients depend to some extent upon the quality of water, and not alone upon the smoothness of

the pipe. In the writer's experience it has been found that reservoir waters carrying microorganisms sometimes foul pipes rapidly, and decrease carrying capacities to an important extent. This has been a vital matter with some pipe lines in this country and in England. The reduction in carrying capacity from organism may be in part, or mainly, temporary, and capacity may be restored soon after the organisms of the particular kind that cause trouble cease to be found in the water through natural causes, or by the application of copper sulphate. On the other hand, the conditions may become chronic with some reservoir waters. The matter is one that must be taken into account, and it will not do to assume that the variation in carrying capacity of concrete pipe is only due to the character of the surface of the pipe itself.

The author is to be particularly commended for making use of various approximate methods of measuring water. If he had insisted upon some one method thought to be more accurate than the others, it would have reduced the number of possible experiments. The methods used by him seem to have been sufficiently accurate. Efforts to obtain precision, while often commendable, may seriously limit the accumulation of useful data.

The writer is pleased to see that the Williams and Hazen formula still holds its own. He has used it in all his hydraulic work for 15 years, and found that, as an all-around working basis of estimate, it answers very well.

There is a distinct advantage in using only one formula, for one becomes thoroughly accustomed to it, accumulates his data in its terms, can much better judge all varying conditions, and is less likely to make errors in its application.

The formula proposed by the author for cement pipes, $V = C_s H^{0.5} J^{0.625}$, is unquestionably a good one and well adapted to the use. As a practical matter, within the ordinary range of velocities, it would not make much difference whether it or the Williams and Hazen formula were used. Only at very low or very high velocities would the difference become considerable.

The formula proposed by the author has some interesting antecedents. The number of exponential formulæ has become so great in recent years that the range of exponents is well taken up, and any exponent that may be selected will be found to have been already used by someone. Thus the Moritz formula referred to by the author at length in his paper is, in reality, the old Lampe formula, which antedates its use by Moritz by several decades. In a similar way the formula now proposed by the author for cement pipe is an old one.

In 1882, Alphonse Fteley, then city engineer of Boston, found that it best accounted for the flow of water at various depths in two sections of the Sudbury Aqueduct.¹ He wrote it: $V = 127 R^{0.62} I^{0.50}$. I stood for inclination, and is equivalent to s now used. (See pipe No. 63, p. 89.)

The formula now proposed by the author was also reached by the writer in 1901 by a reconsideration of hydraulic data presented by Mr. Fenkell.²

¹ Boston Water Works, Additional Supply from Sudbury River, City Document, p. 92.

² Jour. Assoc. Engin. Soc., vol. 26, p. 163.

The formula $V = 130 R^{0.625} s^{0.50}$ was suggested for new pipe (and otherwise with varying value of the coefficient) as being more consistent and quite as accurate as some other procedures that had preceded.

Following this, a simple hydraulic-slide rule was made to calculate pipe friction by it. This permitted a great increase in rapidity of estimate. The writer used these homemade rules for a year or two in his daily work, and made a number of them for his friends. He was well satisfied with the estimates that were reached by their use. Later the interest in hydraulic-slide rules increased, and there was a demand for more of them, and it was decided to have them made in quantity. Before doing this a careful reconsideration of the exponents was made by Prof. Gardiner S. Williams, which led to the adoption of those which have since come to be associated with the Williams and Hazen formula.

This Williams and Hazen formula was intended to represent more accurately all round average waterworks conditions than the earlier one, which was identical with that one now proposed by the author, and the writer thinks that for such general use it is an improvement.

It may be pointed out that a slight variation in the exponents does not make a very great difference in ordinary estimates. Precision in the values of the exponents is not to be expected and is not necessary. It is only desirable that the formula that is used should have exponents that do not differ too widely from the actual facts.

With such a formula the important matter is a study of the coefficients to find out whether these coefficients are affected by variations in the condition and smoothness of pipe surface, and by the character of the water that flows through the pipe. At the present time study of coefficients is much more useful than further study of minute differences in exponents.

The writer is glad to see that the author is taking up his data along these lines.

DISCUSSION BY MR. LIPPINCOTT.

I have had a good deal to do with the construction of large concrete pipes, 10 to 12 feet in diameter, and the following observations may possibly be of interest:

Concrete will expand and contract with wetting and drying in much the same way that it does between heat and cold, and in order to prevent shrinkage cracks coming from drying, the concrete pipe or conduit should be kept just as moist as possible during the period in which it is curing and until it has been actually put into service. In the case of large pipe particularly this can be accomplished by putting some water into the pipe and by closing the ends of the pipe after it is built so as to prevent the circulation of dry air through the pipe. I have known concrete pipe that has developed circular shrinkage cracks which leaked badly when water was first put in and to close up after the water had been running through them for seven or eight days, I believe because of the expansion of the concrete due to its becoming saturated.

By taking pains in the manner suggested with the construction of the Los Angeles Aqueduct in the Mojave Desert, preventing the drying out of the concrete by circulation of air, mile after mile of this ditch could be built without any expansion joints and without any cracks developing.

It is suggested that concrete pipe, especially where it is to be laid on or near the surface of the ground, should where possible be built in cool weather rather than hot weather, both because of the temperature of the air and also on account of the temperature of the water. If the pipe is built in warm weather it is apt to shrink in cold weather and when cold water is run through it in such a way as to develop objectionable circular cracks.

In 1907 or 1908, at the time the Los Angeles Aqueduct was being designed, investigation was made to determine the value of the coefficient n in the Kutter formula in a number of the conduits of southern California. The result of these investigations was published about that time in the Engineering News over my signature. An interesting feature that developed as a result of these investigations was that the carrying capacity of the ditch and the value of the coefficient varied immensely with the question of whether the particular ditch or conduit was exposed to the rays of the sun or whether it was covered. If it were covered, the lining kept clean and smooth, but when it was exposed to the action of the sun a vegetable growth immediately set in. The growth resembled both the lichens on stone and long streaming grass. The result was that we found values of n of about 0.012 for ordinary covered conduits, and anywhere from 0.014 to 0.018 for these uncovered conduits.¹

It was also observed that in ditches where the sand-box arrangements were poor that small bars of sand would follow down the conduit or even through the pipe lines and very materially, in fact totally, change the carrying capacities of the ditch. In other words, the capacity of the ditch is affected by the provisions that are made to remove sand and gravel that might otherwise enter.

My experience is that plastered conduits of any kind should if possible be covered. It has been found by experiments made, I think at the University of Michigan, that the expansion and contraction of concrete varies greatly with the richness of the mix, the richer mixes expanding more than the leaner mixes. It is customary to make the plaster richer than the main bulk of the concrete in order to get a smoother surface. The different rates of expansion and contraction of the body of the concrete and the plaster is largely responsible for the scaling of the plaster. If a plaster is desired it should have about the same ratio of sand to cement as is used in the main mix between sand and cement, and much more labor should be put on than ordinarily in producing the smooth surface. By careful forming in conduits and by troweling it is found to be possible in many cases to obtain a perfectly smooth surface without the use of plaster.

I believe that it is entirely possible to build a jointed concrete pipe that roots will not enter. A number of years ago I made an examination of the irrigation system at Rialto. This was all built of cement pipe which had been in service for a term of years, perhaps 15 or 20. The pipe ran under trees of all classes and kinds—cypress, eucalyptus, orange, and lemon trees and deciduous fruits. We cut into the pipe in many places and by means of mirrors threw the light back through the pipe so that it could be carefully examined. The pipe was clean, in every instance showing evidence of course of

¹ The above experiments are described as Nos. 58, 59, and 60.

very careful work, but demonstrating to my mind that it was possible to build a cement pipe that roots would not enter. This was a jointed cement pipe built by Mr. Stowell, of Los Angeles. The examination was being made for purposes of reorganization.

DISCUSSION BY MR. NEWELL.

With respect to the liability of concrete pipe to show decreased carrying capacity with age, my experience may be of some value. February 26, 1918, I inspected the interior of three concrete pipe lines, the R_1 , D_1 , and M pipes.

R₁ pipe (No. 32 and 33a).—Interior diameter 46 inches; thickness of shell 3 inches; laid in winter of 1909–10; in use 8 years. The interior for several hundred feet from the intake appeared as good as when first laid. The impressions of rivet heads in the steel forms were clearly visible in the concrete. For the first few pipe lengths from the intake there had been a very slight abrasion on the bottom of the pipe. It is over this stretch that the water flows freely when first entering the pipe and down which some gravel rolls.

D₁ pipe (No. 23 and 24a).—Interior diameter 30 inches; thickness of shell 3 inches; laid in February–March, 1910; in use 8 years. On account of the relatively small diameter of this pipe, the inspection did not cover any great distance from the intake end. A little abrasion near the bottom of the pipe was observed for the first few feet; thereafter the pipe appeared as good as new, slight irregularities in the forms being clearly indicated on the concrete.

M pipe.—Interior diameter 47 inches; thickness of shell $2\frac{1}{2}$ inches; laid in winter of 1907–8; in use 10 years. On account of some seepage flow into the pipe, inspection had to be made at the outlet end. As in the other two cases, the interior seemed to be in as good a condition as when the pipe was first laid.

Considering the length of service of the three pipe lines, the fact that they are in use about 7 months each year and dry 5 months, I know of no other type of construction which seems to promise such length of service, coupled with little or no decrease in carrying capacity.

Some have felt doubt as to the permanence of the concrete pressure pipes with thin shells on account of the possible destruction of the steel due to the slow passage of water through the shell. A few days ago we had occasion to cut into the D_1 pipe for the purpose of inserting a valve, and found the steel as bright as when first laid. I am sending you a small section herewith.¹ The sample of steel was taken where the pipe is subjected to a head of slightly more than 40 feet. Samples taken from other pipe lines have uniformly given the same result, indicating that there is little likelihood of deterioration in steel in this type of pipe. I may add that in no case has our reinforced-concrete pipe, built by the wet process, shown any material defects of construction or any sign of deterioration.

¹ To all appearances the steel is new.

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THE ORGANIZATION AND MANAGEMENT OF FARMS IN NORTHWESTERN PENNSYLVANIA.

AN ANALYSIS OF THE BUSINESS OF 422 FARMS IN THE VICINITY OF GROVE CITY, PA.

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OBJECT OF STUDY.

The object of this study was to obtain, through a detailed analysis of 422 farms, information relative to farm organization, crop production, and profits for an area which was representative of numerous similar areas in western Pennsylvania, southwestern New York, eastern Ohio, and parts of West Virginia. The study has a particular significance in view of the changes which have been taking place in the agriculture of this region during the past few years. Until recently the farming practiced throughout this region was of the general crop and live-stock type. Many of the farms are of such size that their operators have found it more profitable to obtain some outside employment during a part of the year than to operate them continuously.

In the spring of 1915 a creamery was organized at Grove City, the market center for these farmers, and an interest in this industry was immediately manifested by many of them. This resulted not only in a general increase in the number of dairy cows in this section

but also in a definite change to the dairy type of farming by a number of these farmers. The present study, covering the farm year 1916, was made two years after the new industry had been introduced.

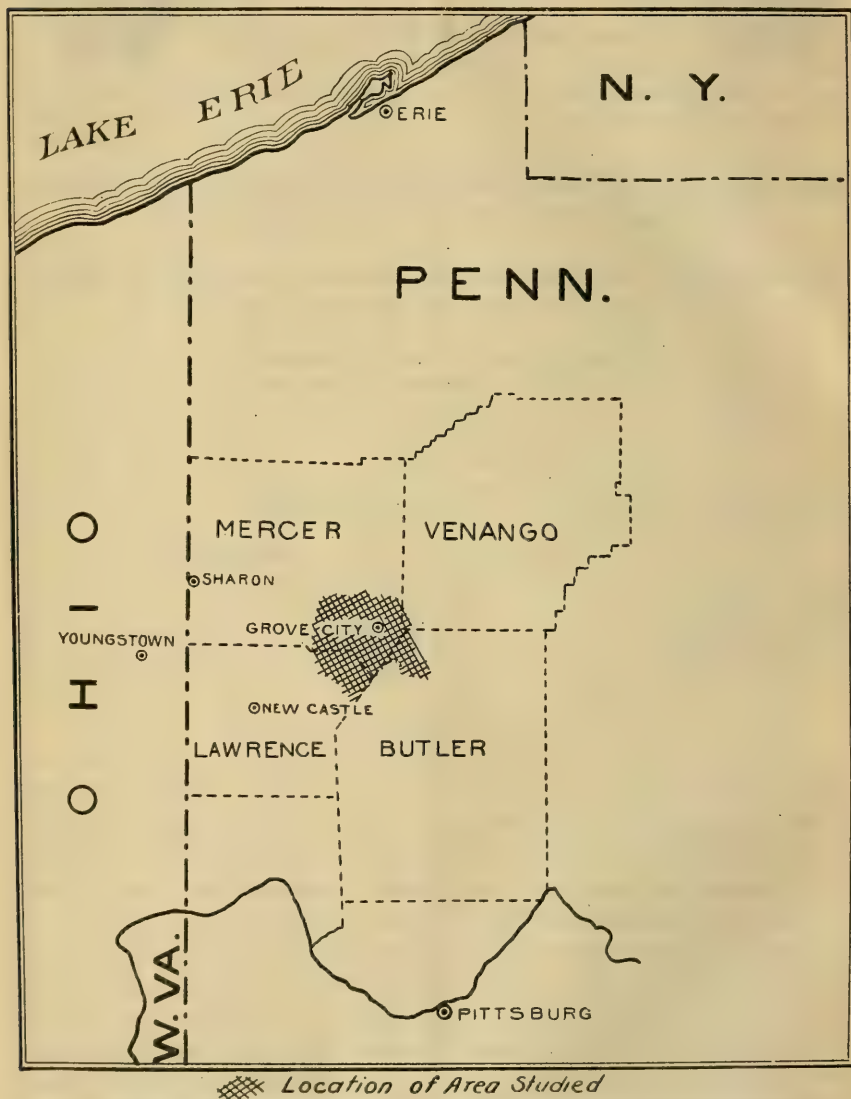


FIG. 1.—Western Pennsylvania, shaded portion showing area where this study was conducted.

SUMMARY OF RESULTS.

The more important facts brought out by this study may be summarized as follows:

Type of farming.—General live-stock and crop farming, until recently the type followed almost exclusively in the Grove City area, is being gradually superseded by the dairy type. At the time of

this survey, 46 per cent of the farms studied might be classed as dairy farms.

Size of farm.—The 422 farms studied averaged 101 acres in size, 60 per cent of the land being tillable. The 40 per cent nontillable was mostly used for pasture. The average value of real estate was \$57 per acre.

Capital invested.—The average capital invested in the dairy farms was \$8,112 and in the general farms \$7,252. About three-fourths of this represented real estate. It required a working capital of \$1,994 to operate the average dairy farm and of \$1,746 to operate the average general farm.

Income.—For the year 1916 the average labor income of 159 dairy farms was \$279; of 190 general farms, \$291.¹

For all farms the amount available for family living averaged \$740. This was in addition to the value of food products, fuel, and use of house furnished by the farm without money cost. The average amount available for family living on the dairy farms was \$773 and on the general farms \$714.

For all farms of 70 acres or under, the average amount available for family living was \$568; for the farms of over 130 acres, it was \$1,152. One-eighth of the men operating farms of over 130 acres made labor incomes of \$1,000 or more, and one-third made labor incomes of \$500 or more.

Receipts.—About three-fourths of the total receipts for all farms came from live stock. Dairy products, cattle, poultry, and hogs were the four leading sources of income. The leading cash crop is wheat, returns from that crop representing over one-fourth of all returns from crops. Wheat, however, occupies but one-tenth of the crop area on the average farm.

¹ Certain terms as used in this bulletin are here defined:

Farm investment.—The value at the beginning of the farm year of all real estate, machinery, live stock, and other investment used to carry on the farm business. It includes the value of the farm dwelling, but not the household furnishings.

Receipts.—The amount received from the sale of crops, the net increase from stock, and the receipts from outside labor, rent of buildings, etc. The net increase from stock is found by subtracting the sum of the amount paid for stock purchases and the inventory value at the beginning of the year from the sum of the receipts from stock products, sales of live stock, and the inventory value at the end of the year. If the value of crops or supplies on hand is greater at the end of the year than at the beginning, the difference is considered a receipt.

Expenses.—The amount of money paid out during the year to carry on the farm business, together with the value of the unpaid labor performed by members of the family. If the value of crops or supplies at the end of the year is less than at the beginning, this is considered an expense. Household or personal expenses are not included.

Farm income.—The difference between receipts and expenses. It represents the amount of money available for the farmer's living above the value of family labor, provided he has no interest to pay on mortgages or other debts.

Labor income.—The amount that the farmer has left for his labor after 5 per cent interest on the farm investment is deducted from the farm income. It represents what he has earned as a result of his year's labor after the earning power of his investment has been deducted. In addition to the labor income the farmer receives a house to live in, fuel (when cut from the farm), garden products, milk, butter, eggs, etc.

Per cent on investment.—The rate returned on the farm investment after the value of the farmer's labor is deducted from the farm income. It represents what the investment earns after all expenses have been deducted and the farmer has received a fair wage for his labor.

The dairy farmers who sold all their milk for butter fat made higher labor incomes than those who sold butter only, or butter part of the year and creamery milk part of the year. These men also realized higher prices per pound for butter than those who sold butter only.

One-seventh of the receipts from live stock came from poultry.

Hogs were kept on nearly every farm, but receipts from hogs were only 8 per cent of all farm receipts.

Less than 3 per cent of the total farm receipts were from sheep.

Receipts from beef cattle were of considerable importance on some of the larger general farms.

Use of silo.—Over one-half of the dairy farmers use the silo. On the dairy farms where silage was fed it was found that only 38 per cent of the feed used was in the form of concentrates, while on those without silage concentrates constituted 47 per cent of the total feed. Production per cow was greater on the farms where silage was used.

AREA STUDIED.

The 422 farms visited in making this study lie within a radius of about 10 miles of Grove City, in northwestern Pennsylvania. The area covered included farms in Mercer, Butler, and Lawrence Counties. More of them, however, were in Mercer County than in either of the others. This study was made in the summer of 1917 in co-operation with the farm management department of the State College of Agriculture, State College, Pa.¹

DESCRIPTION OF THE AREA.

The surface of the region about Grove City is rolling. (See fig. 2.) Most of the area drains into a stream known as Wolf Creek, which crosses it about the center. Bordering this stream and its tributaries are considerable tracts of swamp land, but little of which has been drained. Scattered through the area are quite extensive bodies of timber, consisting principally of hardwoods.

The soils of this region are of glacial origin and mostly belong to the Volusia and Canfield series.² They are the result of feeble glaciation of shales and sandstones. In texture these soils vary from a clay to a coarse sand. On steep areas the soils are generally stony. The alluvial soils of the bottoms are especially variable in texture, ranging from sands to heavy clays. In some of the swamps a considerable amount of muck soil may be found.

¹ Acknowledgment is due to the Dairy Division of the U. S. Department of Agriculture for help and suggestions in planning and conducting the work; to Messrs. E. O. Anderson, of the Pennsylvania Agricultural College; F. Montgomery, C. E. Hope, H. L. Chance, C. E. Miller, of the Office of Farm Management; and J. Coke and J. C. Neale, of the Ontario Agricultural College, who assisted in collecting the field data. Thanks are also extended to the many farmers of the region who furnished the details concerning their farm business which has made this publication possible.

² See soil survey of Mercer County, Pa., 1919.

The principal market is Grove City, though a few farmers sell some of their produce in Harrisville, Mercer, and New Castle, Pa.

Railway transportation is furnished by the Bessemer & Lake Erie and the Pennsylvania Railroads. There are a few miles of macadam road. The Pittsburgh and Erie and the Pittsburgh and Franklin roads, which are kept in somewhat better condition than the average country road, run through portions of the area.

The region has been settled for about 100 years, and the type of farming is general in nature. Until the establishment of the creamery, general crop and live-stock farming prevailed. Since that time, however, much more attention has been given to dairying. The leading crops, from the standpoint of acreage, according to the



FIG. 2.—View showing typical topography of region.

United States Census reports, have been hay, oats, corn, wheat, and buckwheat, arranged in order of acreage, and the relative proportion of the total crop acreage devoted to these crops has changed but little. Similar data show that there has been but little change in the proportion of the different classes of live stock.

THE GROVE CITY CREAMERY.¹

In May, 1915, the Dairy Division of the United States Department of Agriculture organized and began to operate a creamery at Grove City. (See fig. 3.) This creamery has been very successful. Because of the excellence of the products manufactured, patrons have received good prices for their milk.

Indirectly the creamery has been of benefit to the community in that it has served to maintain at a more stable level throughout the

¹ See "How Dairying Built Up a Community," Yearbook Separate 65.

year the prices paid for butter. Many farmers stated that before the establishment of the creamery the hucksters made their own prices, which were very low during the summer months. Now, owing to the keen competition, the prices of dairy products during the months of large production have not been so low as formerly.

The creamery building was constructed according to plans made by the engineers of the Dairy Division and financed by a stock company organized by the business men of Grove City. This building was taken over by the Department of Agriculture on a long-term lease which insured the stock company a reasonable return on its investment. It provides facilities for conducting investigations



FIG. 3.—Creamery at Grove City.

which can not be carried on in the laboratories in Washington, and also provides facilities for studying methods of creamery operation in general.

The creamery buys both cream and whole milk. Principally on account of the large sales of cottage cheese made from skim milk, the creamery has been able to pay good prices for whole milk, and many of the best dairymen are now selling their entire product instead of separating the cream and feeding the skim milk to calves and pigs.

CLASSIFICATION OF FARMS.

Reports from 422 farmers are used as a basis for this study. Sixty-three of these derived the greater portion of their receipts from work off the farm. These cases are discussed under "Income from sources outside the farm," page 30. On 10 farms the greater part of the crop

area was rented out. These farms are discussed under "Tenure," page 31.

On 159 farms the leading enterprise is dairying, and on 190 the farming is general in type. The grouping of the farms into these two types was made on the basis of the size of the business enterprises contributing to the farm income. Farms on which dairying was the leading or one of the important phases of the farm business were classed as dairy farms.

Inasmuch as dairying and general farming represent the two more important types of farming followed in this area, this inquiry naturally developed into a comparative study of the farms following these



FIG. 4.—One of the better dairy herds of the region.

two types. In many ways the dairy and general farms are similarly organized, however, and in order to simplify some of the tables averages are given for both types together, any special differences being noted in the accompanying text.

Until recently the so-called mixed or general type of farming was no doubt better adapted to the majority of farms in this area than a highly specialized type. While dairy farming has not been followed long enough to show any marked increase in profits over the other types, conditions over a large part of this area are especially favorable for the development of dairying. The relatively large acreage and good yields of hay, together with fair yields of silage corn, good pasturage, abundance of good water, and a good market, indicate a promising future for the dairy business. (See figs. 4 and 5.)

TABLE I.—*Summary of the farm business of 159 dairy farms and 190 general farms, Grove City, Pa., area, 1916.*

	Dairy farms (159).	General farms (190).
	<i>Average.</i>	<i>Average.</i>
Farm area.....	97	104
Crop area.....	48	48
Months of man labor.....	17	16
Number of productive animal units ¹	15	13
Number of work stock.....	3	3
Investment.....	\$8,112	\$7,252
Receipts.....	1,366	1,135
Expenses.....	681	482
Farm income.....	685	653
Interest on investment at 5 per cent.....	406	262
Labor income.....	279	291
Value of farmer's labor.....	\$356	\$316
Per cent on investment ²	4.1	4.7
Farm income.....	\$685	\$653
Value of unpaid family labor.....	102	67
Family income ³	787	720
Interest paid on indebtedness.....	14	6
Amount available for family living and savings.....	773	714

¹ Includes all stock except work stock.² After deducting farmer's labor from farm income.³ The sum of farm income and value of unpaid family labor, or the amount available for family living and savings had there been no interest to pay.

FIG. 5.—Farmstead of typical dairy farm of the better class.

In Table I is given a summary of the farm business of 159 dairy and 190 general farms. From this summary can be drawn some comparisons of the size of farm, crop area, amount of labor, amount of live stock, capital, receipts, expenses, and profits. All these factors are of vital importance to those operating farms of these types and those contemplating farming under conditions such as exist here.

The average farm income, which represents the difference between the total receipts and total expenses, was \$685 on the dairy farms and \$653 on the general farms. In the expenses a sum is included for the value of the labor performed on the farm by the farmer's family, which averaged \$102 on the dairy farms and \$67 on the

general farms. Comparing the family income per farm it will be observed that this is \$67 higher on the dairy farms.

The labor income, which represents the amount of money the farmer received for his year's labor after paying all farm expenses, including the value of labor performed by his family, and 5 per cent interest on the capital invested, averaged \$279 on the dairy and \$291 on the general farms. In addition to this these farmers received house rent and what the farm furnished toward the family living.

Figure 6 shows labor income, receipts, and expenses for the 349 farms arranged according to total acreage. Farms of the same total acreage have been arranged according to crop acreage—those having the lowest crop acreage being placed at the left of the acreage group. The upper half of the chart shows labor income (or loss) and the lower half receipts and expenses. The broken and solid bars taken together represent total receipts for the farm, the solid part representing expenses and the broken part farm income; that is, the difference between total receipts and expenses. For a few farms the bars are solid black; this means that on these farms expenses equaled or exceeded total receipts. The dotted lines connecting the two halves of the chart are put in at 10-acre intervals.

This chart furnishes some interesting material for the man contemplating the purchase of a farm where conditions are similar to those prevailing here. For instance, if he has in mind a 60-acre farm, he will see that the farms of this size gave labor incomes of from minus \$67 to plus \$508. Thus the lower half of the chart, showing receipts and expenses, will give him a good indication of what he might reasonably expect to take in as receipts each year and about what proportion of receipts he might expect to pay out for expenses on farms of different sizes operated under such conditions as prevail in the Grove City area.

In studying this chart it should always be borne in mind that there are efficiently operated farms of all sizes, and that not all the poor farms are small. While it is not possible to tell exactly how much money a man on a 60-acre farm in this area ought to make, this chart shows how much several average, several poor, and several good farmers actually did make in 1916. For this reason a study of this chart ought to be a valuable aid to the better interpretation of the tables of averages given elsewhere in the bulletin, as they show the range of possibilities for farms of any acreage.

An interesting group of farms, each of 100 acres, appears at about the middle of the chart. Note the variation in labor income from a minus labor income of \$302 and increasing to a plus labor income of \$1,263. This group of farms of the same size shows that while acreage has an important bearing on labor income, there are a number of other factors that are equally important.

A study of the receipts and expenses of these 349 farms shows that even if one knows the receipts of a farm it is not always possible to tell whether the farm is prosperous, though large receipts seem to be a pretty good indication that a farm in this region is prosperous.

It will be noted that labor income increases from left to right—that is, as the size of farm increases labor incomes increase—also that while the little farms do not yield big incomes, neither do they show big losses.

There are two ways of increasing the farm income. One way is to increase receipts and the other to reduce expenses. Too many farmers give too much attention to reducing expenses and not enough consideration to increasing receipts. By referring to the chart it appears that the principal reason why some of these farmers made more money than others was primarily because they increased receipts and not because they reduced expenses. The lower half of the chart shows that on most farms about one-half of the receipts were required for expenses, though on a few farms expenses equaled or exceeded receipts. On some of the more successful farms and on the larger farms in general a lower proportion of receipts was required for expenses than on the average farm. As mentioned elsewhere, the larger farms have a lower proportionate expense for building, fencing, and machinery repair and depreciation than the small farms. Note that some of the average-sized farms (100 acres for this area) have larger receipts than some of the largest farms. Note that the farm with the largest loss (the largest minus labor income) had an acreage large enough for a fair income; the capital was not excessive for farms of this size, but reference to the lower half of the chart shows that the reason for the loss was that the expenses were out of proportion to the receipts. On this farm the unusually large expense was in part due to heavy bills for hired labor.

Figure 7 shows the distribution of the farmer's gross income. In preparing this chart the 349 farms were arranged in four size-groups. The fifth bar shows the average for all the farms. It will be seen that on the larger farms if the farmer is free from debt the amount available for family living is large, even though there is little or no labor income. This sum is made up of the amount required for interest on investment, the value of unpaid family labor, and whatever labor income there may be. On these farms it totals over \$1,150.

PRODUCTION PER FARM.

The amount of farm products for sale or for use in increasing the size of business is one of the best measures in studying the efficiency of a farm. While it is important that a farm be so organized as to contribute liberally to the farmer's living, a farm can not be considered profitable until it is yielding enough products for sale to

LABOR INCOME, RECEIPTS AND EXPENSES, 349 FARMS, GROVE CITY (PA.) AREA.

FIG. 6.—Labor income, receipts, and expenses for 349 farms, Grove City, Pa., area. The farms are arranged according to total average. Those of same total average are arranged according to crop acreage, those having the lowest crop acreage at the left.

The upper half of the chart shows labor income and the lower half receipts and expenses. The broken and solid bars taken together represent total receipts, the solid part representing expenses and the broken part farm income. The labor-income bars that project below the zero line represent minus labor incomes, or losses.

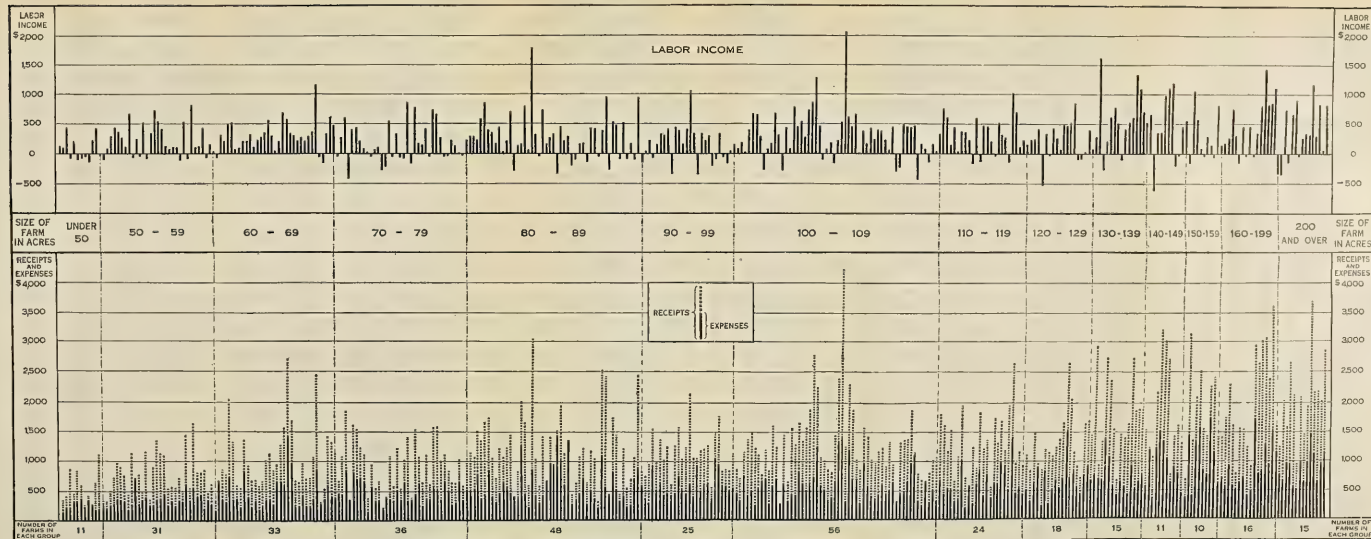
Receipts.—The amount received from the sale of crops, the net increase from stock, and the receipts from outside labor, rent of buildings, etc. The net increase from stock is found by subtracting the sum of the amount paid for stock purchases and the inventory value at the beginning of the year from the sum of the receipts from stock products, sales of live stock, and the inventory value at the end of the year. If the value of crops or supplies on hand is greater at the end of the year than at the beginning, the difference is considered a receipt.

Expenses.—The amount of money paid out during the year to carry on the farm business, together with the value of the unpaid labor performed by members of the family. If the value of crops or supplies at the end of the year is less than at the beginning, this is considered an expense. Household or personal expenses are not included.

Farm income.—The difference between receipts and expenses. It represents the amount of money available for the farmer's living above the value of family labor, provided he has no interest to pay on mortgage or other debts.

Labor income.—The term used to designate what is left for the farmer's labor and managerial ability after deducting from cash receipts and increased inventory all expenses, including an allowance at current rates for the unpaid family labor, depreciation on the equipment, and interest (at 5 per cent) on the value of the farm property. The value of the products consumed by the family and the residence value of the farm house are not included in the income and hence are excluded from labor income.]

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maintain itself adequately as a business organization. By this is meant farm receipts of sufficient amount not only to cover the yearly cash outlay, but to pay for the labor and supervision of the farmer and members of his family, and depreciation and interest on investment as well. After the farmer has obtained these various products,

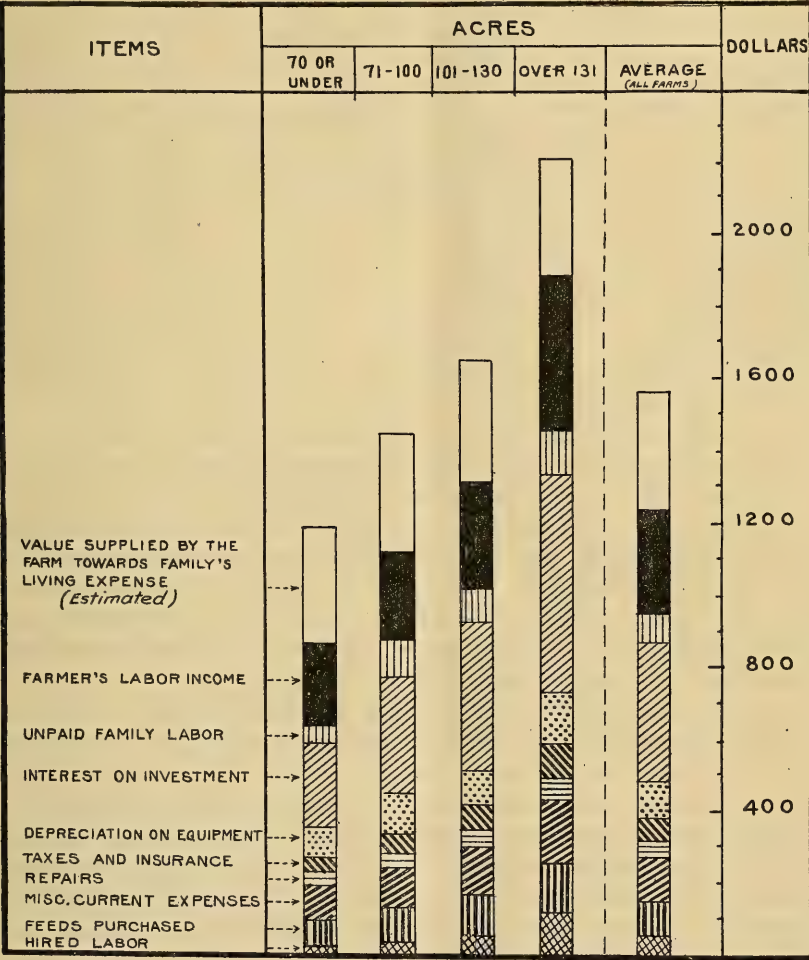


FIG. 7.—Distribution of the farmer's gross income.

he has the option of either turning them into cash or using them in increasing the size of his business.

Table II shows an itemized account of the various farm products, averaged for the dairy and general farms under study. The dairy enterprise was the one showing the greatest development in this area, and most of the dairy cows were kept for increasing the size of the herd. Part of the young stock was kept in this connection, but most of the other products were turned into cash.

TABLE II.—*Products sold or added to inventory per farm on 159 dairy farms and 190 general farms, Grove City, Pa., area.*

Product.	Unit.	Amount per farm.		Value per unit.	
		Dairy farms.	General farms.	Range.	Average.
Dairy cows.....	Head.....	1.8	1	\$40.00 to \$100.00	
Cattle.....	Pound.....	1,565	2,171	.06 to .09	\$0.0779
Horses.....	Head.....	0.3	.2	25.00 to 300.00	
Hogs.....	Pound.....	935	1,235	.08 to .12	.0962
Chickens.....	do.....	338	391	.12 to .17	.15
Sheep.....	do.....	62	543	.065 to .10	.0838
Butter fat.....	do.....	1,122	429	.36 to .52	.43
Eggs.....	Dozen.....	265	273	.20 to .40	.25
Wool.....	Pound.....	5	39	.32 to .65	.36
Corn.....	Bushel.....	4	6	.80 to 2.00	.98
Wheat.....	do.....	22	32	1.55 to 3.00	1.70
Oats.....	do.....	8	16	.70 to 1.00	.72
Rye.....	do.....	1	1	1.10 to 1.60	1.06
Buckwheat.....	do.....	14	16	.60 to 1.20	1.03
Potatoes.....	do.....	19	16	1.50 to 3.00	2.04
Hay.....	Ton.....	2.3	5.1	9.00 to 15.00	11.32
Apples.....	Barrel.....	5	4	1.50 to 3.00	1.83
Strawberries.....	Quart.....	96	6	.08 to .12	.09
Timothy seed.....	Bushel.....	.2	.1	2.50 to 4.00	3.36
Clover seed.....	do.....	.5	.4	8.00 to 13.00	11.46
Maple sirup.....	Gallon.....	2	2	1.00 to 2.00	1.32
Man and team labor.....	Day.....	14	8	3.00 to 5.50	4.54
Man labor.....	do.....	5	10	1.00 to 3.50	2.57

It will be noted that in only two principal sources of receipts did the dairy farms exceed the general in amount produced for sale. The production of cows and butter fat was greater on the dairy farms.

It should not be inferred that all of the farms sold those products, but the figures given simply represent the average of the farms taken as a whole; for example, of the 349 farms only 75 farms reported sales of sheep or wool, 36 of corn, 159 of wheat, 61 of oats, 16 of rye, 101 of buckwheat, 138 of potatoes, 105 of apples, 10 of strawberries, 134 of hay, 37 of clover seed, and 15 of timothy seed.

Woodland also has a share in the farm production of this area. While, as shown in Table IV, the cash receipts from this source were small, its contributions in the way of fuel and repair material for the upkeep of fences and buildings were of considerable importance.

The range of prices is due to the quality of the product at the time of selling, the fluctuations of market prices, and the marketing ability of the farmer selling them. It is hardly practicable to itemize all of the smaller items of farm receipts, but the above list represents over 90 per cent of the farm receipts and all of the principal sources of receipts.

DISTRIBUTION OF FARM AREA.

The farm area on 349 farms in the region considered averaged in size 101 acres, and in respect to utilization was distributed as follows:

Tillable area:	Per cent.
Crop area.....	48
Tillable pasture.....	12
Untillable pasture.....	20
Woodland (pastured).....	10
Woodland.....	4
Waste.....	6

The average size of the dairy farms was 97 acres and of the general farms 104 acres. The general farms had an average of a little over 6 acres more of pasture than the dairy farms. Woods, the greater part of which is used for pasture, occupy about 14 acres per farm. According to estimates made by 168 of these farmers, it takes 3 acres of average woods pasture to equal 1 acre of average open pasture.

DISTRIBUTION OF CAPITAL.

Table III shows the average amount of capital used and its distribution for the dairy and general farms.

TABLE III.—Average capital and its distribution on 159 dairy and 190 general farms, Grove City, Pa., area.

	Dairy farms.	General farms.
Average capital.....	\$8,112	\$7,252
Capital distributed to—	<i>Per cent.</i>	<i>Per cent.</i>
Land.....	42	44
Dwellings.....	16	16
Other buildings.....	17	16
Total real estate.....	75	76
Live stock.....	17	16
Machinery.....	5	5
Feed and supplies.....	2	2
Cash.....	1	1

As shown, about three-fourths of the total capital used in the operation of these farms is in real estate. It may be noted that the capital investment of the dairy farms is somewhat higher than that of general farms. On the dairy farms dwellings average \$1,334 in value, and all the other buildings \$1,369 per farm; on the general farms the average of dwellings is \$1,121 each and all the other buildings \$1,158. The value of real estate for all the farms here under study averaged \$57 per acre.

On the dairy farms the sum of the value of the live stock, machinery, feed, and cash, that is, the working capital, averages \$1,994, and on the general farms, \$1,746 per farm. In other words, if one were to go into this area and buy the average farm of about 100 acres he would need this much additional to invest in stock and tools before he began to farm. Of course, this does not mean that a man would need this total amount in cash in order to buy and stock the average farm, but that he would have to make an investment of that amount.

Too many farmers make the serious mistake of attempting to operate a farm with too little working capital. It is better to have a mortgage on the farm, if necessary in order to provide sufficient working capital, than to have the farm clear and be handicapped because of the lack of stock and adequate equipment.

DISTRIBUTION OF RECEIPTS.

Table IV shows the sources of receipts on the dairy and the general farms.

TABLE IV.—*Sources of receipts on 159 dairy and 190 general farms, Grove City, Pa., area.*

Source.	Distribution of receipts with reference to sources.	
	Dairy farms.	General farms.
	<i>Per cent.</i>	<i>Per cent.</i>
Dairy products.....	38.4	14.2
Cattle.....	21.9	25.1
Horses and colts.....	2.3	4.5
Sheep.....	.5	5.3
Hogs.....	6.8	8.9
Poultry.....	8.7	11.2
All stock.....	78.6	69.2
Wheat.....	2.7	4.9
Corn.....	.3	.5
Potatoes.....	3.0	2.8
Oats.....	.4	1.1
Buckwheat.....	1.0	1.4
Hay.....	1.8	5.3
Apples.....	.6	.6
Other fruit.....	.7	.3
All other crops.....	.6	.9
All crops.....	11.1	17.8
Woodland products.....	.6	1.1
Miscellaneous.....	6.6	6.9
Increase feed and supplies.....	3.1	5.0

There was little difference in the percentage distribution of the various receipts in the different size-groups of farms.

Over 60 per cent of the receipts on the dairy farms was received from the sale of cattle and their products, while this source yielded less than 40 per cent on the general farms. The farms of the latter type had a much higher percentage of their receipts from the sale of live stock other than cattle. Another variation in the distribution of receipts on these two types of farms was from the sale of crops. The general farms sold one and one-half times as much wheat and about two and one-half times as much hay per farm as the dairy farms. Receipts from woodland products averaged \$11 per farm, comprising \$3 from maple sirup and \$8 from lumber or wood. Other receipts upon these farms, grouped as miscellaneous, amounted to \$83 per farm, and consisted principally of receipts from hauling coal and doing other team work.

DISTRIBUTION OF CROP AREA.

Table V shows the distribution of the crop area on 349 dairy and general farms in the Grove City area.

TABLE V.—*Distribution of crop area on 159 dairy farms and 190 general farms, Grove City, Pa., area.*

	Dairy farms.	General farms.
Average crop area (acres).....	48	48
Total crop area in—	<i>Per cent.</i>	<i>Per cent.</i>
Hay.....	47.6	48.1
Oats.....	16.2	16.4
Corn.....	16.2	14.4
Wheat.....	9.0	10.3
Buckwheat.....	3.9	3.9
Rye.....	1.6	1.4
Apples.....	3.5	3.8
Potatoes.....	1.5	1.4
All other crops.....	.5	.3

There was little variation in the distribution of the area devoted to different crops on the two types of farms. More corn and a little less hay and wheat are grown on the dairy farms than on the general farms. The leading crop, measured by acreage, is hay, which occupies nearly one-half of the crop area. The leading grasses are timothy and clover. On the dairy farms the corn from one-third of the acreage devoted to corn was put in the silo, while less than 1 per cent of the corn acreage on the general farms was handled in this manner.

The grain crops raised in this area, in the order of their importance, are oats, wheat, buckwheat, and rye. A comparison of the area devoted to each of these on the two types of farms shows practically no difference except in the case of wheat. For the farms reporting wheat the average area per farm devoted to this crop was 4.8 acres on the dairy farms and 5.4 acres on the general farms.

Some fruit is grown throughout this area, but it is used mostly for home use.

DISTRIBUTION OF LIVE STOCK.

Table VI shows the distribution of live stock on 349 dairy and general farms in the Grove City area.

TABLE VI.—*Distribution of live stock on 159 dairy and 190 general farms, Grove City, Pa., area.*

	Dairy farms.	General farms.
Total live stock per farm (animal units) ¹	18	16
Animal units represented by—	<i>Per cent.</i>	<i>Per cent.</i>
Dairy cows.....	44	28
Other cattle.....	22	30
Horses and colts ²	21	23
Sheep.....	1	5
Hogs.....	7	8
Poultry.....	5	6

¹ An animal unit is a mature horse or cow, or as many smaller animals as require the feed of a horse or cow, namely, 2 head of young cattle, 5 hogs, 7 sheep, or 100 hens.

² Includes 3 head of work stock.

On dairy farms, the dairy cows made up 44 per cent of the total number of animals, when expressed in the terms of a mature cow or horse, and 28 per cent on the general farms. On the dairy farms 66 per cent of the total number of animal units were cattle, and on the general farms 58 per cent. Seven per cent of the other cattle were beef cattle and 19 per cent young cattle, bulls, or breeding stock.

Two and seven-tenths per cent of all the animal units were colts. On the 349 farms 80 colts were raised during the year, or 1 for every 13 horses kept.

Most of the sheep in the area are found on the general farms. Only 3.1 per cent of all the stock on the 349 farms were sheep.

About 90 head of poultry were kept per farm.

EXPENSES.

The expenditures for most purposes were practically the same on the two types of farms under study. The dairy farms, however, had an average expense of \$199 more per farm than the general farms, due principally to extra expenditure for feed and labor.

In operating a farm there is a direct relation between the type of farming and the percentage of receipts required for operating expenses. Fifty per cent of the total farm receipts were required for operating expenses on the dairy farms and 42 per cent for operating expenses on the general farms. Taking both groups together, 46 per cent of the receipts were required for operating expenses.

TABLE VII.—*Distribution of expenses on 159 dairy and 190 general farms, Grove City, Pa., area.*

Item.	Distribution.	
	Dairy farms.	General farms.
	<i>Per cent.</i>	<i>Per cent.</i>
Hired labor and board.....	9.0	9.2
Family labor.....	15.0	13.9
Repairs:		
Machinery.....	1.6	1.5
Buildings.....	4.0	4.8
Fences.....	1.6	2.3
Feed bought:		
Hay, etc.....	.9	.6
Grain, etc.....	21.1	10.4
Breeding fees and veterinary.....	1.7	1.9
Seeds.....	2.5	4.2
Fertilizer.....	4.7	6.4
Thrashing and clover hulling.....	1.9	2.5
Baling, machine work, fuel, and oil.....	1.6	2.6
Insurance.....	1.2	1.5
Taxes.....	8.1	11.4
Milk hauling.....	3.2	1.2
Miscellaneous ¹	5.0	5.5
Total current expenses.....	83.1	79.9
Depreciation:		
Buildings.....	9.3	11.0
Machinery.....	7.6	9.1

¹ Includes feed grinding, silo filling, fodder shredding, horseshoeing, spray material, twine, pasture rent, and barrels.

Seventeen per cent of all the expense of the farms was for feed. On the dairy farms cost of feed averaged 22 per cent of the total farm expense, and on the general farms 11 per cent. The average feed bill on the dairy farms amounted to \$149. On the 349 farms taken as a whole, 26 per cent of the total farm expense was for repairs and depreciation on buildings, machinery, and fences. In other words, over one-fourth of the total farm expense was for maintenance of property.

Fourteen per cent of the expense was for family labor, 9 per cent for hired labor, and 10 per cent for taxes. All the other expenses were small, the only two that amounted to more than 3 per cent of the total farm expenses being fertilizers, 5.4 per cent, and seeds, 3.3 per cent.

Analyzing the expenses by size-groups, we find that on the farms with an area of 70 acres or under 30 per cent of the total farm expense was for repairs, depreciation of buildings, machinery, and fences, while on the group of largest farms, those with an area of 130 acres or over, these items amounted to 24 per cent of the total farm expense. This serves to emphasize the fact that, in general, the larger the farm of a given type the lower proportionately will be the maintenance expenses; that is, the larger farms show greater efficiency in that machinery, buildings, and fencing expenses are proportionally reduced.

Fourteen per cent of the farmers rented additional pasture land, usually parts of tracts without buildings or of lands held by mining companies, the houses thereon being occupied by miners. Those renting thus usually pay about \$1 per acre, as this is not good pasture land, being usually grown up with brush or partly in woods. Where it is rented by the month, the price is usually 75 cents to \$1 per head of stock pastured per month. The average expense for pasture hire on the farms that rented was \$21.20 per farm.

SIZE OF FARM, ORGANIZATION, AND PROFITS.

Twenty-three per cent of the farms covered in this study were 70 acres or under in size, while 18 per cent contained over 130 acres. By dividing the farms into four groups, those containing 70 acres or under, those of 71 to 100 acres, those of 101 to 130 acres, and those of over 130 acres, a series of averages is obtained that should be of practical value to the farmers of this region. The dairy farmer with 70 acres or under is thus enabled to note how the average farm following this same type is organized and operated in this region. Like comparisons may be drawn for each of the four size-groups.

A number of factors, such as labor requirements and live stock returns, differ considerably in the operation of a dairy farm as com-

pared with that of a general farm, and for this reason separate tables are presented showing data on these fundamental factors of efficiency for each type.

DAIRY FARMS.

In Table VIII is shown a summary of the farm business on 159 dairy farms, arranged in groups according to size of farm.

TABLE VIII.—*Summary of the farm business of 159 dairy farms, Grove City, Pa., area.*

	Averages by farm area groups.			
	70 acres or under.	71 to 100 acres.	101 to 130 acres.	Over 130 acres.
Number of farms.....	37	66	32	24
Farm area (acres).....	57	88	113	161
Crop area (acres).....	33	43	54	75
Months of labor.....	15	17	19	22
Productive animal units.....	10	13	17	22
Work stock.....	2	3	4	4
Investment.....	\$5,606	\$7,259	\$9,318	\$12,712
Receipts.....	1,010	1,218	1,532	2,098
Expenses.....	484	607	771	1,067
Farm income.....	526	611	761	1,031
Interest on investment at 5 per cent.....	280	363	466	635
Labor income.....	246	248	295	396
Value of farmer's labor.....	\$349	\$337	\$370	\$399
Per cent on investment ¹	3.2	3.8	4.2	5
Farm income.....	\$526	\$611	\$761	\$1,031
Value of unpaid family labor.....	57	106	110	153
Family income ²	583	717	871	1,184
Interest paid on indebtedness.....	15	7	16	32
Amount available for family living.....	568	710	855	1,152
Crop yields per acre ³	102	100	104	98

¹ After deducting farmer's labor from farm income.

² The sum of farm income and value of unpaid family labor, or the amount available for family living had there been no interest to pay.

³ Percentage of average for all farms.

The dairy farms 70 acres or under in size with an average of 33 acres of crops, 10 units of productive live stock, and \$5,606 capital, returned the operator a labor income of \$246. In operating farms of this size it required 15 months of man labor and an average of over two work horses per farm.

On the farms of over 130 acres in size, 75 acres of crops were raised and 22 productive animal units were kept per farm. With \$12,712 capital these farms returned their operators an average labor income of \$396. An average of 22 months of man labor per year was required in operating farms of this size and nearly four work horses.

The per cent returned on investment, found by deducting the value of the farmer's labor from the farm income, varies from 3.2 per cent on the smallest size-group to 5 per cent on the farms in the largest size-group.

In operating farms under conditions similar to those in this area the family income is of much interest, as it is the amount of money

available to pay living expenses, interest on indebtedness, and savings. The family income averaged \$583 on the farms of the smallest size-group, and increased with each size-group to an average of \$1,184 on the largest size-group.

GENERAL FARMS.

Table IX shows a summary of the farm business on 190 general farms arranged in four groups according to size of farm.

TABLE IX.—*Summary of the farm business of 190 general farms, Grove City, Pa., area.*

	Averages by farm area groups.			
	70 acres or under.	71 to 100 acres.	101 to 130 acres.	Over 130 acres.
Number of farms.....	44	64	42	40
Farm area.....	56	86	113	177
Crop area.....	31	44	50	70
Months of labor.....	13	15	15	20
Productive animal units.....	8	12	13	21
Work stock.....	2	2	3	4
Investment.....	\$4,308	\$6,573	\$7,388	\$11,432
Receipts.....	733	1,016	1,149	1,755
Expenses.....	307	443	477	742
Farm income.....	426	573	672	1,013
Interest on investment at 5 per cent.....	216	329	369	572
Labor income.....	210	244	303	441
Value of farmer's labor.....	283	319	311	353
Per cent on investment ¹	3.3	3.9	4.9	5.8
Farm income.....	\$426	\$573	\$672	\$1,013
Value of unpaid family labor.....	30	60	67	116
Family income ²	456	633	739	1,129
Interest paid on indebtedness.....	2	9	11	1
Amount available for family living.....	454	624	728	1,128
Crop yields per acre ³	102	99	95	103

¹ After deducting the value of farmer's labor from farm income.

² The sum of farm income and value of unpaid family labor, or the amount available for family living had there been no interest to pay.

³ Percentage of average for all farms.

Here, also, it will be seen that labor income increases with size of farm. The average labor income for the smallest size-group averaged \$210 and that of the largest size-group \$441. The percentage returned on investment ran from 3.3 to 5.8 per cent.

It will be noted that, taken as a whole, the general farmers made labor incomes averaging \$12 per farm higher than those of the dairy farmers. However, it will be noted that the average labor income on the two groups of small-sized dairy farms was slightly higher than on corresponding size-groups of the general farms. While the average size of the dairy farms of these two groups was slightly larger than for the corresponding groups of general farms, the main reason for the larger labor incomes is that the dairy business is the more intensive. It is evident that the small general farms are not so well

organized, neither are they so well adapted to conditions which exist in this area as are the dairy farms of corresponding size.

Table X shows all farms, by size-groups, classified according to labor income.

TABLE X.—*Number of farms in each size-group making labor incomes as specified (349 dairy or general farms, Grove City, Pa., area).*

Farm area group.	Number of farms in group.	Number of farms with labor incomes of \$1,000 and over.	Number of farms with labor incomes of \$500 to \$999.	Number of farms showing labor loss.
70 acres or under	81	1	12	18
71 to 100 acres	130	3	21	33
101 to 130 acres	74	3	12	13
130 acres and over	64	8	21	15
Total	349	15	66	79

This table shows the chance these farmers have, when operating farms of the various sizes shown, of making a large income.

On the 81 farms 70 acres or under in size, only one operator made a labor income of \$1,000 or over, and only 13 made incomes of \$500.

In the group of largest farms, those of 130 acres and over in size, one-eighth made labor incomes of \$1,000 or more, and nearly one-half labor incomes of \$500 or more.

The three preceding tables serve to emphasize what has been brought out in every similar study conducted by the Office of Farm Management thus far, namely, that the smaller farms (except those operated under intensive methods near good markets) are relatively less profitable than the larger ones. In farming, as in every other business, the man with large capital has a much better chance of getting a large income than the one with little capital. It took a capital of \$11,912 to give an average labor income of \$424 in this area, this being the average capital of 64 farms of 130 acres and over in size.

Often large incomes are made by farmers operating small farms intensively, but in such cases the investment is relatively large. Farm management studies uniformly indicate that the farmers with little capital invested make little money. Size of business is just as important with the farmer as with the merchant.

EFFECT OF YIELDS PER ACRE AND RETURNS FROM LIVE STOCK ON LABOR INCOME.

We have seen in Tables VIII, IX, and X that the larger farms make more money in this area than the smaller ones, and the question arises naturally whether this is due to higher yields or simply to greater production.

Table XI is designed to show the crop yields and live-stock returns for the different size-groups of farms expressed in percentage of the average yields of all farms, known as the crop index.¹

TABLE XI.—Average crop and live-stock index on 349 farms, Grove City, Pa., area.

	70 acres or under.	71 to 100 acres.	101 to 130 acres.	Over 130 acres.
Crop index.....	102	99	99	101
Live-stock index.....	102	100	99	99

This table shows that there is very little difference in the crop yields and returns per unit from live stock on the farms of different sizes.

The crop yields expressed in percentage of the average for all farms in the region were 101 per cent on the dairy and 99 per cent on the general farms. The live-stock returns were 111 per cent of the average for the region on the dairy and 91 per cent on the general farms. This does not mean, however, that the live stock on the dairy farms was 20 per cent more profitable than that kept on the general farms. On the dairy farms the receipts per animal unit were higher, but the feed cost per animal unit was also higher, owing to the more expensive feeds consumed by the dairy stock. On the general farms, where more beef cattle and sheep are produced, the returns are comparatively lower than dairy receipts, but the farmers are able to produce these at a much lower feed cost; and the net profit from such stock may be as high as from the dairy stock.

The crop index on the large farms was practically as high as on the small farms, indicating that the old belief that the small farms produce on the average the highest crop yields per acre is not justified by results in this area.

¹ The crop index may be defined as the crop yields of a particular farm expressed in percentage of the average crop yields of all the farms in the community. It is found as in the following example:

A particular farm produces—

	Acres.
2,000 bushels of corn on.....	40
1,200 bushels of wheat on....	40
900 bushels of oats on.....	30
120 tons of hay on.....	80

Total..... 190

The average yields of the above crops in the community are: Corn, 60 bushels; wheat, 32 bushels; oats, 40 bushels; and hay, 1½ tons per acre. Hence, on the average, the areas required to produce the above quantities of the products mentioned are—

2,000÷60=33.3 acres of corn,
1,200÷32=37.5 acres of wheat,
900÷40=22.5 acres of oats, and
120÷1½=68.6 acres of hay.

Total=161.9

Thus, it requires 190 acres on the farm in question to produce what 161.9 acres produces on the average. Hence, 1 acre produces on this farm 161.9÷190, or 85.3 per cent as much as the average acre of the community.

The live-stock index is the percentage comparison of the receipts per animal unit on farms weighted by their receipts, using as the basis the average receipts of all farms in the area expressed as 100.

Table XII shows the effect upon labor income of improving the quality of the stock and increasing the crop yields. Yields per acre and returns per productive animal unit were found to bear the same relation to labor income on dairy farms as on general farms; hence for the sake of brevity the figures for the two groups have been tabulated together.

TABLE XII.—*Effect of yields per acre and returns per productive animal unit on labor incomes, by size of farm, 349 farms, Grove City, Pa., area.*

LABOR INCOME.

Group.	Live-stock index. ¹			
	100 acres or under.		Over 100 acres.	
	100 or less.	Over 100.	100 or less.	Over 100.
Crop index: ¹				
100 or less.....	\$41	\$285	\$134	\$398
Over 100.....	224	452	340	576

¹ For definition of these terms see page 21.

In order to eliminate the effect of size of business as much as possible, the farms were arranged into two groups. As would be expected, the groups having crop yields and live-stock returns above the average made the most money. This table shows, moreover, that in an area like this, where so great a percentage of the returns is from live stock, it is better to make an effort to improve the quality of the live stock than to try to grow better crops and feed them to poor live stock. Those farmers operating either large or small farms whose crop yields were below the average of those produced in the region, but with live-stock receipts above the average, made higher labor incomes than those having live-stock receipts below the average and crop yields above the average.

LIVE STOCK.

We have seen in Table XII that the farms with crop yields and live-stock returns above the average made more than average labor incomes, and have observed the effect of increasing the receipts per unit of live stock. Table IV showed that over 14 per cent of the receipts on general farms and 38 per cent of the receipts on the dairy farms were from dairy products. It would seem, then, that one of the most direct and effective ways of increasing the income of the farmers of this region is to follow those practices that tend to increase production per cow.

Accurate data were obtained on 265 farms, averaging 6 cows per farm, where the cows were kept for dairy purposes, which showed that the average sales of butter fat per cow was 116.6 pounds. This

is a rather low production per cow. It was possible to get accurate data of the butter fat sold per cow on 123 of the 159 dairy farms, but for the rest of the dairy farms it was not possible to get this figure accurate enough for these tables, because some of the dairymen sold market milk in Grove City or Harrisville, and others shipped this product for a part of the year to Youngstown, Ohio, and to New Castle, Pa. Some farmers sold market milk locally to miners and others living in the area.

The average labor income of the 123 farms furnishing butter-fat data was \$259, while the average labor income of all the dairy farms was \$279. This indicates that the 123 farms are fairly representative. The pounds of butter fat sold per cow and the labor income of the farms selling butter only, of those selling creamery milk, and of those selling both butter and creamery milk is shown in Table XIII.

TABLE XIII.—*Sales of butter fat per cow and labor income of 123 dairy farms selling products as specified, Grove City, Pa., area.*

	Number of farms.	Number of cows per farm.	Pounds but- ter fat sold per cow.	Average labor in- come.
Farms selling—				
Butter only.....	19	6	129.2	\$79
Creamery milk.....	75	8	150.8	325
Butter and creamery milk.....	29	7	125.1	208

The farmers who sold butter and no other dairy products received an average of 35 cents per pound for their butter-fat product. Those selling butter and creamery milk received 41 cents per pound, and those who sold only to the creamery 43 cents. Those who sold to the creamery received 8 cents per pound more for their butter fat than those who sold butter only, or about one-fourth (24 per cent) more per pound. If the farmers who sold butter only had shipped their product to the creamery and had averaged the same production of butter fat the receipts per cow would have averaged \$10.34 higher, and as these farms averaged 6 cows per farm would have received \$62 per farm greater income. There were 82 general farms that sold butter only, and their sales of butter fat per cow were 84.5 pounds, which brought them an average of 33 cents per pound. With the same production per cow, other things being equal, they would have received \$8.45 more per cow and \$40 greater income per year if their milk had been sent to the creamery.

Most of the farmers of the area keenly realize the advantage of shipping their milk to the creamery, and the number of patrons of the plant is increasing rapidly. They also realize the need of improving the quality of their herds. One cow-testing association and two bull associations have been formed since April 1, 1917.

During the period April 1, 1916, to April 1, 1917, the 349 farmers bought for their farms 32 head of pure-bred Holsteins, 13 pure-bred Jerseys, 6 pure-bred Guernseys, and 5 pure-bred Shorthorns. In addition to the above pure-bred cattle, many began to improve the quality of their herds through the purchase of good grade stock and also by using pure-bred bulls.

Ten per cent of the total farm receipts and about one-seventh of the stock receipts were from poultry. The receipts from poultry exceeded those from any class of live stock except cattle, were nearly as great as the combined receipts from hogs and sheep, and were over two-thirds as much as the receipts from crops. Fifteen per cent of the farms of the area sold over \$200 worth of poultry and eggs per farm. Some of the farmers got good returns from turkeys. Not many ducks or geese were kept in the area. A reasonable increase in the amount of poultry, including turkeys, would seem warranted on many of the farms, especially on the farms with an abundance of family labor. Increased attention could be given to the poultry business without any interference with the major operations of the farm.

The receipts from hogs made up 8 per cent of all the farm receipts, besides furnishing an average of 594 pounds of pork per farm for family use. Hogs were kept on nearly every farm, except some that sold whole milk to the creamery or as 'market milk.

Receipts from sheep made up less than 3 per cent of the total farm receipts. The coarse-wool sheep predominated and the Shropshire was the principal breed. Only about 1 farmer in 12 following the dairy type kept sheep, while they were kept by one-third of the general farmers. The flocks averaged 15 head and produced 12 lambs per flock.

There were a few farms in the area where the stock sales were principally from beef cattle, but not enough of them to justify drawing any definite conclusions relative to the comparative profitability of dairy cattle and beef cattle.

During the year of the survey the prices received for beef cattle were relatively higher than the prices received for dairy products, and consequently the beef-cattle farms would show a little higher labor income on the average than would an equally efficient group of dairy farms. Steers were kept on most of the general farms. The labor income of the general farms is a little higher than that of the dairy farms. On some of the larger farms very good returns were realized last year from beef cattle.

It is probable that beef cattle can be raised at a profit on many of the larger farms, particularly those having large areas of rather wet pasture not adapted to sheep raising. Beef cattle require much less care than dairy cows, and where there is a shortage of labor on the farm the raising of beef cattle may be advisable.

Bulletin 150 of the Pennsylvania State Agricultural College, "Raising Beef Cattle," furnishes good data on raising beef cattle. Part of the conclusions set forth in this bulletin are as follows: "Beef production is adapted to and will be found profitable under Pennsylvania conditions on land valued at \$60 or less per acre that can maintain cows at the rate of 2 acres per head during the pasturing season, and on which corn can be raised for silage."

CROPS.

For comparison with crop yields received on these farms for the year under study, corresponding yields as given in the United States Census reports for the years 1900 and 1910 are here presented. The average yields of the three counties in which the survey was made, as given in the last two census reports, are taken together to give a figure applicable to the whole area.

The yield of corn for the year covered by this study was about normal, being 34 bushels per acre as compared with yields of 33 and 32 bushels given in the last two census reports for these three counties. On well-drained land an excellent crop of corn was harvested in 1916, but on many fields a large part of the corn was soft and of poor quality. Silage yielded an average of $7\frac{1}{4}$ tons per acre. Most of the seed corn planted for grain is produced on the farm, but a considerable part of the seed for silage corn is bought. The climate here is less favorable for corn growing than that of many other areas. It is highly advisable to have a vigorous, early-maturing strain of corn, that yields well. Each farmer should make an effort to improve his strain of corn, which can be done quite easily by field selection of the seed.

The yield of wheat was the same as that given for the area in the last two census reports. Wheat was the principal cash crop of the area, 3.8 per cent of the total farm receipts and over one-fourth (26 per cent) of the receipts from crops being from sales of this grain. The average yield in 1916 was 16 bushels per acre, and the average amount sold per farm reporting was 61 bushels.

There are some farms in this area not well adapted to wheat on which rye could be introduced into cropping systems with profit. Rye is hardier than wheat and will grow on poorer soils.¹

The average yield of oats for the year of the survey was 30 bushels, as compared with census figures of 34 and 26 bushels. This crop occupies 16.3 per cent of the crop area of all the farms under consideration. It is an important crop in this area and nearly all of it is fed on the farm. Much of the grass seeding is put in with oats. Smut causes some damage to the crop each year, and a few farmers

¹ For more details concerning the growing of rye, see Farmer's Bulletin 756, "Culture of Rye in the Eastern Half of the United States."

have been using the formaldehyde treatment for it. By the use of this simple and inexpensive treatment the losses from oat smut can be reduced to a minimum.¹

The yield of buckwheat was 15 bushels per acre, as compared with yields of 16 bushels per acre for the census reports of 1900 and 1910.² About one-third as much land is devoted to buckwheat as to wheat. Buckwheat is a good crop to put on rough or weedy land. A good deal of buckwheat is sold, some is used in the house, and a large quantity is fed to the chickens. It makes an excellent chicken feed.

The average yield of hay for the year 1916 was 1.7 tons per acre. The yield of this crop in the three counties in which the survey was made, for the United States Census of 1900 and 1910, respectively, was 1.1 and 1.2 tons. The hay crop in this area was large in 1916, but farmers generally said that the feeding value was somewhat lower than usual. Hay is the leading staple crop of the region, and consists principally of clover and timothy. Much of the red clover seed used is grown on the farm. This is the medium red variety. The alsike clover seed used is purchased. A considerable part of the timothy seed required for farm use is obtained by stripping the heads from selected portions of the hay field. With care, seed of an excellent quality can be obtained by this method. Some of the farmers leave patches of timothy hay standing for seed. A few use the barn-floor sweepings for their source of supply of timothy seed.

The yield of potatoes was somewhat below normal, 68 bushels per acre, as compared with yields of 102 and 93 bushels given in the last two census reports. The higher prices obtained, however, would about make up for the loss due to low yield. Potatoes, however, are a relatively unimportant crop in this area, occupying but 1.5 per cent of the total crop area, or about seven-tenths of an acre per farm.

Little attention has been paid to orcharding in this area. Few of the farmers spray their trees, and many do but little pruning. In one part of the area surveyed one farmer who runs a special fruit farm does considerable spraying for his neighbors, using a small power sprayer. This farmer sold \$175 worth of apples, \$300 worth of cherries, \$100 worth of peaches, \$100 worth of plums, and \$124 worth of strawberries. A small quantity of pears and prunes were produced and sold in this area.

In general, market conditions are such that it would be inadvisable to increase to any great extent the acreage devoted to truck crops in this area, yet on many farms, especially on those where there is a large family at home, the addition of some special crop like strawberries, raspberries, or blackberries would materially increase

¹ For information in controlling cereal smuts see Farmer's Bulletin 939, "Cereal Smuts and the Disinfection of Seed Grain," which may be obtained free from the U. S. Department of Agriculture.

² For further details concerning the growing of buckwheat, see Farmers' Bulletin 1062, "Buckwheat."

the farm income with practically no expense for extra hired labor in picking. Some farms in this area have soil adapted to the growing of onions, much of which is not being utilized, except for general farm crops. If some of this land were devoted to the onion crop the farm receipts would be considerably increased, and in most cases all of the extra labor required could be done by the family.

Table XII shows that it is more important to increase the quality of the live stock than to increase the crop yields. However, one must not lose sight of the fact that it is very important to maintain crop yields.

FARM FEEDS AND THE SILO.

The use of silos is becoming quite general, there being 113 on the 349 farms studied when this survey was made. Eighty of these silos were on dairy farms. Thus over one-half of the dairy farmers were using silos. During the farm year 11 new silos were built. The average yield of corn for silage was 7½ tons per acre, and on several farms the yield was over 10 tons.

It was possible to obtain accurate figures of the pounds of butter fat per cow on 56 dairy farms that had silos and on 67 farms that had none. Table XIV shows the average investment per farm, average crop acres per man, total feed units required per animal unit, the average number of cows per farm, the sales of butter fat per cow, and the labor income on 56 dairy farms having silos and on 67 dairy farms without silos.

TABLE XIV.—Average investment per farm, average crop acres per man, average feed units¹ required per animal unit, average number of cows per farm, the sales of butter fat per cow, and the labor income on 56 dairy farms having silos and 67 dairy farms without silos, Grove City, Pa., area.

	Average investment per farm.	Average crop acres per man.	Average feed units per animal unit.	Average number of cows per farm.	Average pounds of butter fat sold per cow.	Average labor income.
56 farms with silos.....	\$9,013	27	3,481	9	151.5	\$346
67 farms without silos.....	6,610	32	3,336	6	132.8	187

¹ A "feed unit" represents the feed value of a pound of corn or its equivalent.
 1 bushel corn=56 feed units. 1 ton bought feed=2,000 feed units.
 1 bushel wheat=60 feed units. 1 ton fodder (stover)=500 feed units.
 1 bushel oats=29.1 feed units. 1 ton silage=333 feed units.
 1 bushel rye=56 feed units. 1 ton hay=800 feed units.

Feed units computed according to table in Wisconsin Circular No. 37, June, 1912.

Farmers having silos on their farms fed a little more heavily than those without silos, but they also got a considerably higher butter-fat production per cow. Upon comparing the proportion of concentrates in the feeds consumed on the two groups of farms, it is found that 38 per cent of the total feed units on the farms having silos were concentrates, while on the other farms concentrates

averaged 47 per cent of the total. One of the reasons for this lower proportion of concentrates fed on the farms with silos is that good silage itself contains some corn and is therefore partly a concentrate, and also that less concentrate is required, because of the succulent nature of the feed.

Although the cows on the farms having silos produced 18.7 pounds of butter fat more per cow than those on the farms without silos, it should not be assumed that this difference or the corresponding difference in labor income is due wholly or even largely to the silo. The farmers with silos were better all-around farmers than those without. They had a larger average investment per farm, worked more crop acres per man, and had more and better cows. The silo was therefore only one of the several factors contributing to their success.

CROPPING SYSTEMS.

A common rotation on many of the farms is corn or potatoes followed by oats, and then by hay two years or longer. Where wheat is grown, the rotation usually is corn, oats, wheat, hay two or three years. Buckwheat is generally sown on the rougher land or land that has become foul with weeds. On some farms buckwheat follows oats in the rotation and serves as a nurse crop for the grass seed. On many farms the hay is cut as long as it gives a fair yield. Some of the meadows do not run out in four or five years. A few farmers are trying out a rotation of corn, wheat, hay, hay.

Judging by the percentages of area devoted to each crop, it would appear that the rotation most generally practiced is corn and potatoes, oats, wheat, rye or buckwheat, and hay three years.

MAINTENANCE OF SOIL FERTILITY.

One of the important problems of this region is that of keeping up crop yields. The test of good farm management is not only the earning of a good current net income, but the keeping up of the fertility of the soil as well. To keep up this fertility, the farmer must rely on the use of manure, lime, fertilizer, and legumes. Practically the only legumes grown here are red clover and alsike. On the farms where manure is produced in sufficient quantity, manure spreaders were used with very satisfactory results. Too many farmers, however, still practice the wasteful method of throwing the manure outside under the eaves of the barn and hauling it to the field but once or twice a year.

FERTILIZERS.

Commercial fertilizers are quite extensively used. Fifty-one per cent of the farmers concerned in this study used fertilizers on corn, 45 per cent on wheat, 47 per cent on buckwheat, and 36 per cent on oats. Most of the farmers used less than 150 pounds per acre.

Acid phosphate was used by many farmers. Some, however, used more expensive fertilizers. Mixing acid phosphate with stable manure in the barn was not practiced to any extent.

In order to show the effect upon crop yields of increasing the amount of fertilizer and manure used per 100 acres of crops, the 349 farms were grouped as shown in Table XV.

TABLE XV.—*The effect upon crop yields of applying different amounts of fertilizer and of live stock kept on 349 farms, Grove City, Pa., area.*

Animal units per 100 acres of crops.	Fertilizer per acre.								
	None.			100 pounds or under.			Over 100 pounds.		
	Animal units per 100 acres of crops.	Fertil- izer per acre.	Crop in- dex.	Animal units per 100 acres of crops.	Fertil- izer per acre.	Crop in- dex.	Animal units per 100 acres of crops.	Fertil- izer per acre.	Crop in- dex.
35 or under.....	25	<i>Pounds.</i> 0	82	28	<i>Pounds.</i> 55	92	28	<i>Pounds.</i> 174	98
Over 35.....	43	0	100	45	63	107	44	160	109

Farmers using over 100 pounds of fertilizer per acre of crops and keeping less than 35 animal units per 100 acres of crops failed to produce as high crop yields as the farmers who used no fertilizer but had



FIG. 8.—Limestone prepared for burning. Either coal or wood may be used.

over 35 (or an average of 43) animal units per 100 acres of crops. The highest crop yields were obtained by the group using over 100 pounds of fertilizer per acre and keeping over 35 animal units per 100 acres of crops. The crop yields on these farms were 9 per cent above the average of all the farms. The lowest crop yields were on the group

of farms where no fertilizer was used and with the least density of live stock, the crop yields on these farms being only 82 per cent of the average. These men had little manure to apply and also overlooked the importance of heavier applications of fertilizer in order to offset the lack of farm manure.

The soils of this area are naturally acid, and the use of lime has been found to give very good results. It is always advisable to use lime to insure a good stand of clover. Lime is quite commonly applied to small grains like oats or wheat. Some farmers use ground limestone. In the southeastern part of the area surveyed there were several limestone quarries and small coal mines. Many of the farmers living near these buy the limestone and coal and burn their own lime. (See fig. 8.)

Information as to the use of lime on soils, with specific directions for applying, may be found in Farmer's Bulletin 921, "The Principles of the Liming of Soils."

The lime is usually distributed by hand.

INCOME FROM SOURCES OUTSIDE THE FARM.

Records were obtained from 63 farms where over one-half (56 per cent) of the receipts were derived from outside sources. These farms averaged 71 acres in size with 35 acres in crops. The average total capital per farm was \$4,893, receipts \$896, expenses \$448, farm income \$448, interest on capital \$244, and labor income \$204.

On the average, these 63 farmers spent 139 days at outside labor. The earnings during the time spent off the farm averaged \$3.50 a day. Much of the money earned outside was derived from either working in coal mines or else hauling coal from the mines to the railroad. (See fig. 9.) Some worked in limestone quarries. Day labor, work with sawmills, lumber business, labor on roads, school-teaching, milk-hauling, and carrying mail all contributed to the receipts from sources outside the farm business.

As would be expected, crop yields were somewhat lower on those farms where nearly one-half of the time of the operator was spent doing outside work. With some operators, farming was their work during their spare time. This is usually the case where there is plenty of outside work available. Because of the immediate returns it offers, outside work looks especially attractive to those in need of money, while the returns from many farm enterprises do not come in at given intervals of time.

For the study of the management of small farms in this area we have three types: those operated where over one-half of the receipts are received from work off the farm, those operated as general farms, and those operated as dairy farms. That the introduction of dairy-

ing into this area has been an advantage in this connection is shown by a comparison of the relative profits received on the farms operated under each of these types. Taking the farms of 70 acres or under in size, there were 38 on which over 50 per cent of the receipts were from work off the farm, the average labor income received being \$192, while the average for those following the general type of farming was \$210, and for those following the dairy type \$246. The farmers following the dairy type had on the average more capital invested than was necessary in following either of the other types, but the additional income received, together with the added advantage of having steady employment throughout the year at home, and in the main being emancipated from the directing authority of others, makes this type the more attractive.



FIG. 9.—Hauling coal from mine. One of the principal sources of outside receipts.

TENURE.

Records were obtained from 10 farm owners who rented out a part of their crop acreage. For the most part these men were considerably older than the average, thus making it necessary for them to get rid of a part of the responsibility of operating the entire farm, yet they continued to live on the farm. The average farm area was 117 acres, with 40 acres in crops, 10 acres of which was rented out. Their total capital was \$7,330, average receipts \$1,019, expenses \$642, farm income \$377, interest on capital \$366, and labor income \$11.

Sixteen farms in the area were operated by tenants. Three of these were dairy and 13 were general farms. The operators paid cash rent. After the landlord's farm expenses, consisting of building depreciation and repair, upkeep of fences, insurance, and taxes, were deducted from the rent received, the landlords received 2.6 per cent on their investment.

Fifty-four farmers in the area increased the size of their business by renting additional land from companies owning land for coal

mines or limestone quarries, or from miners living on small tracts of land, or from men owning small tracts and doing very little farming.

The crops most commonly put in on shares were small grains. The division of the crop and expenses varies greatly. A division that is quite common is for the renter to get two-thirds of the crop, he paying two-thirds of the thrashing and fertilizer bill and furnishing all the seed. In other cases he pays all the fertilizer and two-thirds of the thrashing expense.

Where the renter gets one-half of the crop, quite commonly he pays all the thrashing bill and the owner furnishes all the seed and pays the fertilizer expense.

Where additional hay land is rented, the renter usually gets from one-third to three-fourths of the crop harvested, depending upon the quality and yield and the ease of harvesting. Though only a small amount of corn land was rented out, the renter of such land usually paid for one-half of the fertilizer, did all the work, and received one-half of the grain and stover.

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PROFESSIONAL PAPER

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THE FLOW OF WATER IN DRAIN TILE.

By D. L. YARNELL, *Senior Drainage Engineer*, and SHERMAN M. WOODWARD, *Professor of Mechanics and Hydraulics, State University of Iowa.*

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INTRODUCTION.

The discharging capacity of tile drains has become a matter of considerable importance in recent years, on account of the heavy investments being made in this kind of agricultural improvement. Drain tile in small sizes have been used for a long time, but recently much larger sizes, 2 feet and more in diameter, have come into rather common use in some States. Where tile 24 to 48 inches in diameter and larger are to be installed, at a cost of \$8,000 and upward per mile, reducing the diameter 2 or 3 inches may mean saving \$500 to \$1,500 per mile.

Planning the best tile-drainage system for any situation is a complicated problem of balancing many diverse and uncertain factors of benefit and cost. The point of largest rate of return upon the investment can not be determined exactly. Obviously, a point may easily be reached, where additional expenditure, although se-

curing an enhanced degree of drainage, would not yield additional benefit in proportion to the increase in cost, and might not be justified. On the other hand, an inadequate installation might be so ineffective as not to justify even the small expenditure it would require. It is the engineer's high duty, therefore, in planning the general scheme of improvement for any drainage undertaking, to determine just what expenditure will yield a satisfactory return, and to so proportion the details as to secure the maximum benefit from the investment. A deficiency at one point may reduce the effectiveness of the whole system, while the elaboration of one part out of proportion to the others might add materially to the expense without obtaining any benefit.

The formulæ in general use for computing the velocity of flow in tile drains were proposed years ago, when all drain tile were small as compared with the larger sizes used to-day. Under the earlier conditions, when other considerations had relatively large weight in determining the size of tile to be used, accuracy in computing carrying capacity was relatively unimportant; but nowadays drains 12 to 48 inches in diameter are common, and accurate knowledge of the capacity is essential for economical design.

Although many experiments have been made upon flow of water in iron, steel, concrete, and wood-stave pipes, the results are not directly applicable to tile drains. The tile usually are not nearly so regular in size and shape as are the other pipes mentioned, and specially noteworthy is the number and nature of the joints. While the other conduits are either of continuous construction or in 10 to 20 foot lengths, drain tile are in lengths of only 1 to 3 feet. Furthermore, with clay tile the nature of the materials used and the methods of manufacture are the causes of some distortion in cross section; this is particularly noticeable where two lengths abut. The considerable unevenness at the joints, when multiplied by the greater number of joints, so greatly disturbs the flow of water as to make formulæ devised for other kinds of conduit inapplicable to tile drains.

Realizing the need for accurate knowledge regarding the flow of water in tile drains, plans for investigating this subject were made by the drainage division of the Bureau of Public Roads, early in 1915. The experiments so far made concern only the smaller sizes of tile, and this report therefore should be considered as a progress report of the investigation of the whole subject.

SCOPE OF THE INVESTIGATION.

Drain tile installed for agricultural improvement serve two somewhat distinct purposes—as collectors of excess water and as conduits to convey the water to some more or less distant outlet, but usually both purposes are served coincidentally. The investigation herein

reported, however, deals only with the discharge or carrying capacity of tile drains as conduits. No tests were made on sizes smaller than 4 inches in inside diameter, as the use of smaller sizes now is considered generally inadvisable, the small bore greatly increasing the danger of obstruction by sediment or by displacement.

Laboratory methods are essential for securing definite results in such an investigation, in order that each factor influencing the flow may be varied through a considerable range, yet always subject to control, while the other factors are maintained constant. Only in this manner can each influence be measured separately. The factors influencing the velocity of flow in a tile drain are: the inside diameter of the pipe, the depth of the water flowing, the slope or grade of the water surface (which ordinarily is that of the tile line), and the roughness and irregularity of the interior surface and of the joints. On tile lines installed for actual use in land drainage the grade of each line is fixed; most of the time they are empty or carry but little water; the amount of flow depends upon weather and seasons and can not be regulated for investigation; and when the flow is considerable the weather is likely to be bad, the roads practically impassable, and the ground surface covered with water—conditions that make it impossible to secure satisfactorily precise measurements in tile several feet under ground.

The principal feature of the equipment for making the experiments was a wooden flume about 570 feet long, in which the tile were laid in earth exactly as drains are installed in the ground. The flume was adjustable to any grade up to 1.50 per cent ($s=0.015$), without disturbing the tile. The depths of flow were observed by piezometer tubes hung on the side of the flume. Care was taken to make the tile lines truly representative of drains ordinarily well laid under field conditions.

Experiments were made with all the usual commercial sizes of tile, both of clay and of concrete, from 4 to 12 inches inside diameter. Nine grades were used, from 0.05 to 1.50 per cent, for each size and kind of tile. For each size, kind, and grade it was desired to test depths of flow of one-fourth, three-eighths, and one-half the internal diameter of the tile, and other depths ranging from half full to full by successive increases of 5 per cent of the diameter. However, because of the practical difficulty of securing exactly any given depth of flow, the number of tests was considerably less than anticipated in the smaller sizes of tile. Also, the capacity of the pumping plant was not sufficient to fill the largest tile at the maximum grade. Tests were run, also, with the tile under slight internal pressure. In all, 824 separate tests were made, and from these a new formula has been devised for computing the flow in drain tile.

For comparison, 69 tests were made on 10 and 12 inch tile, so laid as closely to approximate poorly laid drains as found in the field, to show the results of using unskilled workmen in laying drains without proper supervision. Nine experiments were made upon the loss of head in catch-basins, using 8-inch clay tile. Grades of 0.20, 0.75, and 1.50 per cent were tested, with drops in the catch-basin of 0.10, 0.20, and 0.30 foot for each grade.

The investigations were made at Arlington, Va., in 1916 and 1917. The experimental plant was designed and constructed by S. W. Frescoln, drainage engineer, and the tests were made by D. L. Yarnell, senior drainage engineer, under the direction of S. H. McCrory, chief of drainage investigations. S. M. Woodward acted as consulting engineer for the investigation, making suggestions in the conduct of the experiments and collaborating in the preparation of the data and report.

This report upon the investigation of flow in drain tile includes a detailed description of the equipment and methods used and the tabulated data from the experimental work. The results deduced from the data are shown graphically, the method of developing the curves being explained. The formulæ now in general use for computing velocity in tile are discussed and comparison is made with the new formula presented. A diagram is given showing discharge capacities based upon this formula, covering sizes from 4 to 48 inch tile, and grades from 0.04 to 3.00 per cent.

So far as the writers have been able to learn, only one other similar investigation of this subject has ever been made. This was by Messrs. J. F. Rightmire and M. E. Chappel and was quite limited in extent (see Vol. IV, No. 4, Bulletin of the Iowa State College Engineering Experimental Station).

CONCLUSIONS.

The following general conclusions have been drawn after a detailed study of all of the experimental data:

(1) That the value of the coefficient of roughness, n , in the Kutter formula, as obtained by experiments in a drain or pipe at any depth of flow less than full, does not necessarily apply to that drain or pipe when flowing full.

(2) That the exponent of the slope, s , is practically 0.5. In other words, the loss of head is in proportion to the 2.0 power of the velocity and not the 1.8 power, as given by many authorities.

(3) That the exponent of the mean hydraulic radius, R , is $2/3$.

(4) The Chezy formula gives the same velocity of flow in a pipe flowing one-half full as in one flowing full, with the grade constant. The experimental data obtained seem to disprove this commonly accepted theory.

DESCRIPTION OF EXPERIMENTAL PLANT.

PUMPING PLANT.

A complete pumping plant was installed to supply the water necessary to carry on the tests. The pump used was an 8-inch side-suction centrifugal pump. Its economical capacity was 1,800 gallons per minute. The suction pipe, 10 inches in diameter and approximately 40 feet long, was laid sloping from the pump to the intake ditch or sump. The discharge pipe, 8 inches in diameter, was so arranged that the entire capacity of the pump could be delivered to the supply tank with the least frictional losses.

The pump was run by a 30 h. p. engine rated at 200 r. p. m. It was equipped with an oscillating-type magneto with the make-and-break spark. It was started on gasoline, and after becoming warm operated on kerosene. The engine was connected to the pump by a 10-inch, double thickness, endless leather belt.

SUPPLY TANKS.

In order to maintain a constant flow through the tile line, a supply tank 7 feet 9 inches by 7 feet 9 inches by 10 feet 9 inches deep (*A*, Pl. I) was built to receive the pump discharge. On the side of this tank opposite the entrance of the pump discharge pipe, a measuring weir and a hook gage were installed. A baffle board extending from the top of the tank to within 2 feet of the bottom was constructed. Thus the movement of the water from the discharge of the pump was quieted sufficiently to obtain a quiet surface on the water at the hook gage and weir.

Since the entire discharge of the pump was not required for all the experiments, an overflow tank (*B*, Pl. I) was built. Its size was 9 feet 6 inches by 9 feet 6 inches by 5 feet 6 inches deep. A trough from this tank carried the overflow water back to the intake ditch.

For regulating the flow into the supply tank, an 8-inch gate valve was inserted in the pump discharge pipe. This valve is shown in Plate I, between tank *B* and the pump house. The water not required for the experiment passed through another 8-inch gate valve into the overflow tank. When the entire discharge from the pump was used in the tile, the gate valve in the overflow tank was closed.

Another tank containing baffle board, hook gage, and weir was used at the lower end of the tile line to measure the discharge from the tile as a check on the amount of water entering the tile. However, the measurements from this tank, as will be explained later, were not used in the final computations.

Both weir tanks were covered with boards to prevent any surface movement on the water being set up by winds.

WEIRS.

For use in measuring the water entering into and discharging from the tile line, brass, triangular-notch weirs were used, the notch angle being 90 degrees (Pl. II, fig. 1, and Pl. III, figs. 1 and 3). For tile over 4 inches in diameter, weirs with $\frac{1}{8}$ -inch lips were used; while for the 4-inch tile, knife-edged weirs were deemed the most accurate. The weir plates, both of which were set level, were so placed that the nappe of each weir cut free and was fully aerated.

To determine the discharge over the weirs, V. M. Cone's formula,

$$Q = 2.487 H^{2.4805}$$

was used in all computations. In this formula, Q = discharge in cubic feet per second and H = head in feet on weir notch.

HOOK GAGES.

Boyden hook gages were used to determine the head on the weirs. On both gages the vernier plates were securely fastened and bradded to the gage, so as to eliminate any error due to possible charge of position of the plates. Each gage was set at a distance of over $2H$ to the side of the weir so as to record the correct head on the weir.

FLUME.

In order to test the carrying capacity of the tile bedded in earth as in actual practice, a continuous wooden flume (Pl. IV) 570 feet long, 2 feet wide, and 2 feet deep was constructed of 2-inch plank. All joints and seams were calked with oakum and covered with pine pitch to make the flume water-tight. This continuous channel or flume was supported on yoke blocks suspended by $\frac{3}{4}$ -inch steel rods (A , Pl. V) from 6 by 6 inch caps (B , Pl. V) which rested on 4 by 4 inch vertical posts (C , Pl. V). Two vertical posts with their yoke block formed a bent; the bents were spaced 8 feet apart. In all, 72 bents were erected. Each bent was braced by 4 by 4 inch posts (D , Pl. V).

METHOD OF CHANGING GRADE.

The upper 6 feet of the steel rods were threaded with 10 threads to the inch. For support on the caps, bearing plates with ogee washers and 2-inch hexagonal nuts were used. To raise the flume an inch at any bent it was necessary to turn the nuts just 10 revolutions. Ordinary wrenches were cumbersome and slow for turning these nuts, consequently specially-constructed socket wrenches (Pl. VI, fig. 1) were used, consisting of hollow pipes so shaped as to fit over the nuts and with circular disk handles. This type of wrench greatly facilitated the work of changing grade.

To decrease the amount of work necessary to adjust the grade of this continuous channel, the flume was rotated about its longitudinal center. Thus, when changing grade, one half of the flume would be lowered while the other half would be raised. The flume could be set to any grade up to 1.50 feet in 100 feet.

To enable the workmen to determine whether the flume was at the proper grade, graduated wooden strips (A, Pl. VI, fig. 1) 2 inches wide, 0.5 inch thick, and several feet long were placed on each side of the flume at each bent. The difference of elevation between various grades at each bent had been previously computed, and these differences were marked on the gage strips with the corresponding grade number. Thus, when the proper mark appeared at the cross board through which the gage strip ran, the workmen knew that part of the flume to be at the desired grade. At points where the required change of elevation was considerable, the flume was not raised or lowered the entire amount at one time, but was changed by successive increments of only a few inches. Thus the amount of stress on the flume was lessened, and the liability of leakage through the possible springing of the planks was eliminated.

The grade of the flume was checked with an engineer's level immediately before each experiment, to eliminate all possible errors from inaccurate adjustment or from settlement of the vertical posts.

LAYING THE TILE.

The tile were laid on earth in the flume as in actual practice. This earth in the bottom of the flume was about 7 inches deep. It was placed in layers, 2 inches at a time, and each layer was thoroughly tamped so that the bed on which the tile rested would not settle. At first a line was stretched along the flume immediately over its center and about 3 feet above the grade, and this line was used to grade the bed for the tile. It was soon found, however, that the gage line was in the way of the workmen, and another method for grading the tile bed was adopted. The material for this method consisted of a 30-inch strip, 2 inches wide and 0.75 inch thick, and a gage stick of the same size but $17\frac{1}{4}$ inches long. The workman laid the strip across the top of the flume and, holding the top of this gage stick flush with the top of the cross arm, determined whether the invert of each tile was at grade (P. VI, fig. 2).

COVERING THE TILE.

While blinding the tile, an engineer was constantly in the flume to oversee the work and prevent any tile from being pushed out of line. Fine earth, free from large clods, was used for blinding, the inspector tamping the earth on each side of the tile with his feet. Thus any appreciable movement or current of water through the earth on

either side of the tile in the flume was prevented. After the tile were covered, the remaining space in the flume was filled with earth.

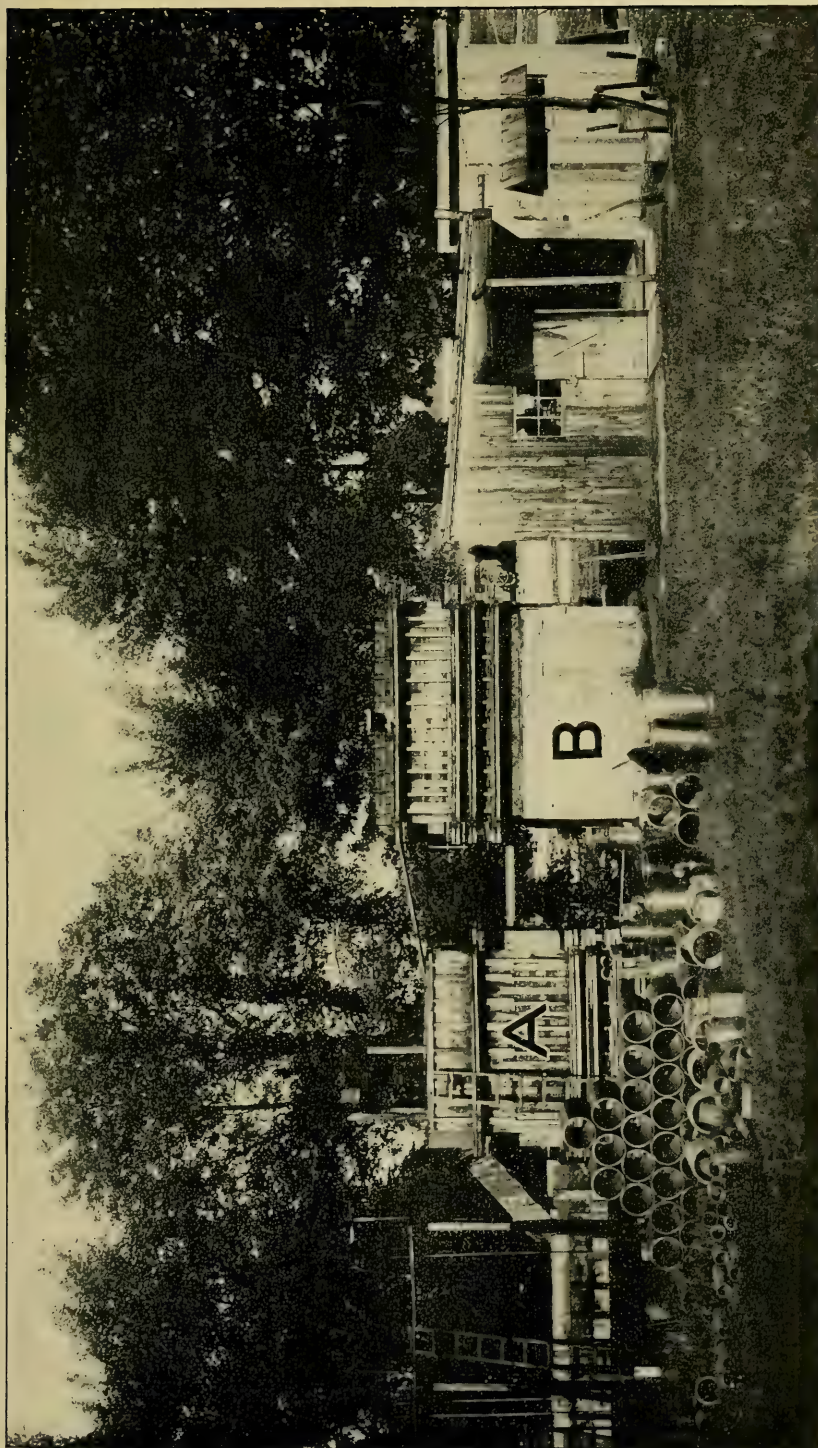
PIEZOMETERS AND PIEZOMETER TILES.

In order to measure the depth of flow in the tile drain, piezometer tubes of graduated glass were placed on the side of the flume and connected to the lower part of the tile line. Twelve tiles of uniform shape, for each size and kind, were selected, and a small hole was drilled through the wall of each. In each hole a $\frac{1}{4}$ -inch iron pipe, 2 inches long, was inserted, care being taken that the tube did not project inside the tile bore. This tube was set in cement (Pl. II, fig. 2), and any unevenness on the inside wall of the tile at the entrance of the tube was removed by coating the surface with a little cement. This method of inserting the tube was deemed the best as determined by Hiram F. Mills from a study of the results of some 6,000 observations on various piezometer connections (see Trans. Amer. Academy of Science, 1878). Mills found that with an orifice whose edges are in the plane of the side of the conduit and with the bore of the tube normal to the plane of the wall, the piezometer column indicates the true height of the water surface in any open conduit, or the pressure in a closed conduit.

At first these piezometer tile were so turned as to have the tube on the bottom of the tile in the flume. Much trouble was experienced from the tube openings filling up, so the piezometer tile were then laid with the tube leading toward the side of the flume but turned slightly downward. The connection was made by rubber tubing to a steel nipple inserted through the wall of the flume (Pl. VII). On the side of the flume at each piezometer tile, a frame holding the glass tube was set. This glass tube (Pl. VII) was graduated in tenths and hundredths of a foot. Its zero was set at a definite distance below the top of the flume. A rubber tube connected the piezometer glass to the nipple in the wall of the flume.

The zero of each piezometer gage was $17\frac{1}{2}$ inches below the top of the flume. The invert of the tile in the flume was always laid $16\frac{1}{2}$ inches below the top of the flume. The capillarity of the glass tubes used was found to be 0.01 foot. Thus, with water just entering the tile drain, the piezometer tube read 0.09 foot. In other words, in order to obtain the true depth of flow in the drain, 0.09 foot was subtracted from each piezometer reading.

With the exception of the two piezometers near the tile entrance, which were only 8 feet apart, these tubes were distributed along the flume approximately 55 feet apart, the last piezometer being within a few feet of the outlet of the tile drain.



B. P. R. D-698

OVERFLOW AND SUPPLY TANKS.

Note arrangement of piping to the tanks. Engine house at right.



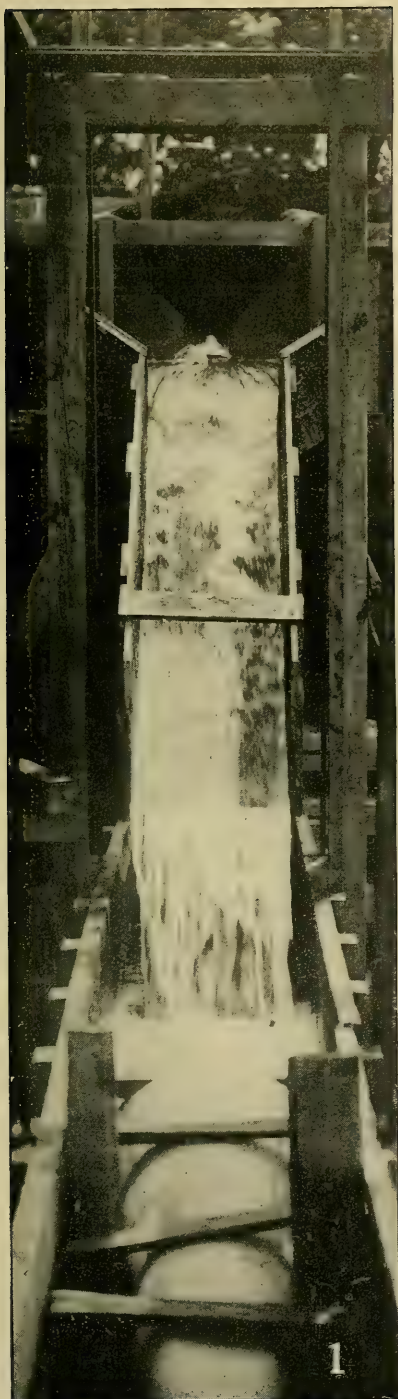
FIG. 2.—PIEZOMETER TILE.

Note tube set flush with inside wall of tile.



FIG. 1.—WEIR WITH 90-DEGREE NOTCH.

Note free fall of discharge from supply tank.



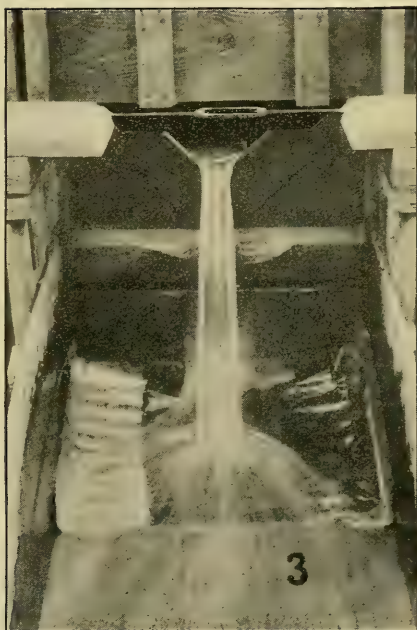
B. P. R. D-537

FIG. 1.—CONICAL ENTRANCE USED TO INCREASE ENTRANCE VELOCITY INTO TILE.



B. P. R. D-534

FIG. 2.—CONICAL ENTRANCE USED TO INCREASE ENTRANCE VELOCITY INTO TILE.



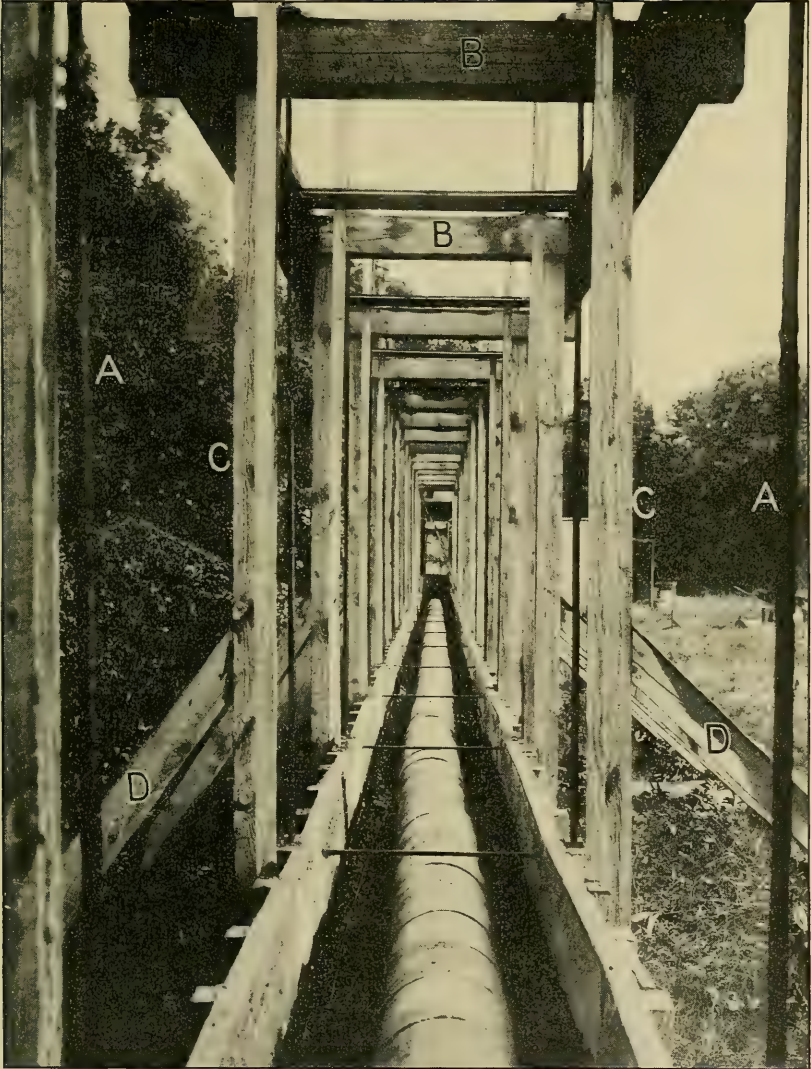
B. P. R. D-691

FIG. 3.—WEIR WITH 90-DEGREE NOTCH.
Note free fall from discharge tank.



GENERAL VIEW OF UPPER END OF FLUME, SHOWING ENGINE HOUSE AND OVERFLOW AND SUPPLY TANKS.

B. P. R. D-524



B. P. R. D-700

UPPER END OF FLUME, SHOWING 10-INCH CONCRETE TILE LAID READY FOR BLINDING.



B. P. R. D-528

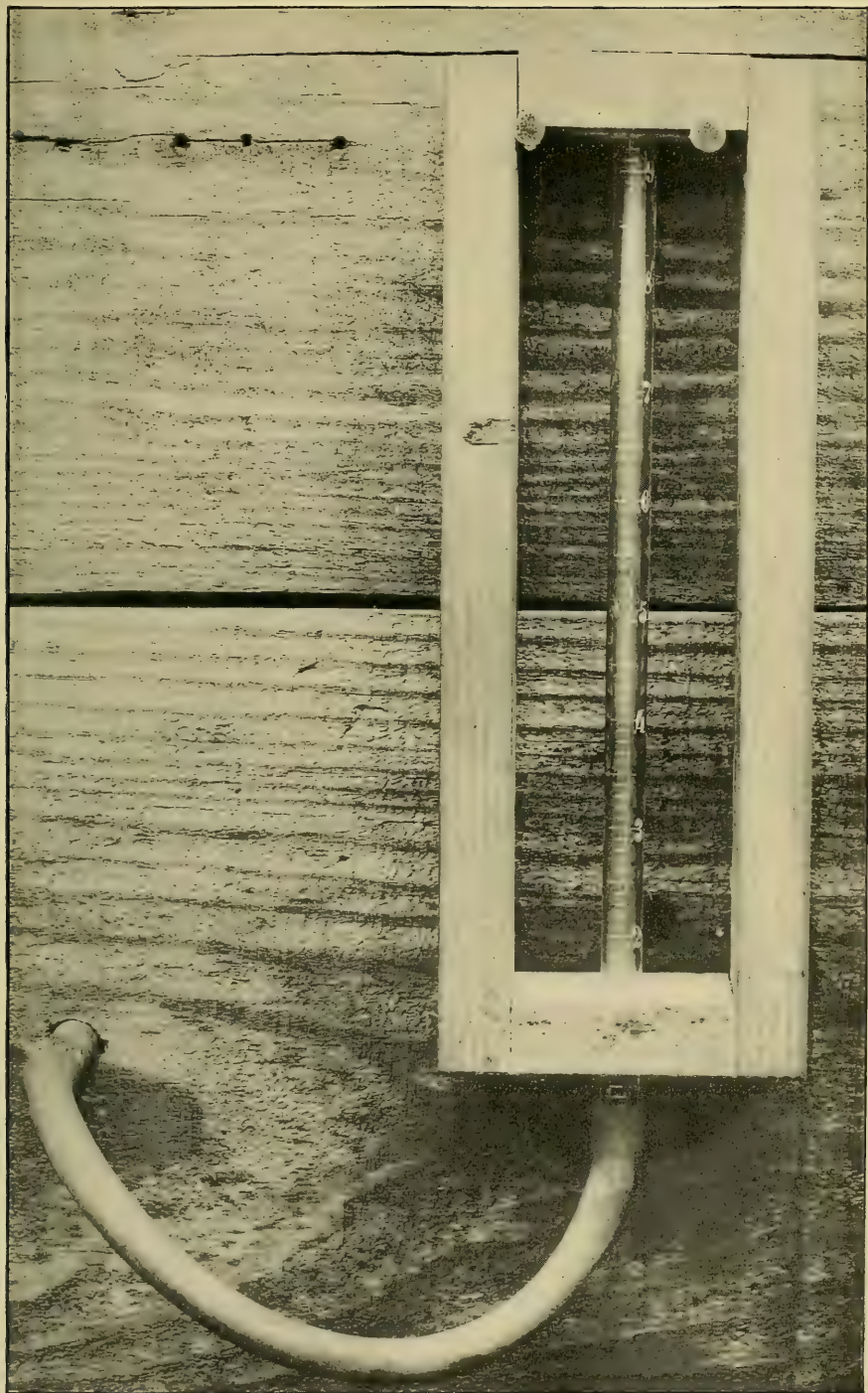
FIG. 1.—CHANGING THE GRADE OF THE FLUME.

Note 12-inch plank laid along top of flume for men to work on while changing grade.



B. P. R. D-599

FIG. 2.—LAYING 10-INCH CONCRETE TILE IN THE FLUME.



B. P. R. D-522

GRADUATED PIEZOMETER GLASS, FRAME, AND RUBBER TUBE CONNECTION TO
PIEZOMETER TILE INSIDE OF FLUME.

NOMENCLATURE.

The following symbols are used throughout this report:

d =mean depth of flow in the drain, in feet.

D =mean inside diameter of the tile, in feet.

r =mean inside radius of the tile, in feet= $\frac{1}{2} D$.

Q =mean discharge of the tile during the test, in second-feet.

A =mean area of the tile bore, in square feet= πr^2 .

a =average area of flow in the tile, in square feet.

V =mean velocity of the water during the test in feet per second= $\frac{Q}{a}$.

P =wetted perimeter in the tile, in feet.

R =mean hydraulic radius= $\frac{a}{P}$; in a tile drain running full $R=\frac{D}{4}$.

s =hydraulic grade or slope.

n =coefficient of roughness in Kutter's formula.

C =coefficient in Chezy's velocity formula.

C_w =coefficient in the Williams-Hazen velocity formula.

h =total difference in elevation between ends of a main drain, in feet.

l =length of the drain tested, in feet.

b =summation of the amounts of excess head in the submains, in feet.

T =number of submains.

U =depth of the soil over the main drain at its head, in feet; used only when main drains are 1,000 feet or more in length.

$s=mv^z$ is the general equation for the flow of water in drain tile, in which z is always constant and m varies only with the size of tile.

$m=eD^x$ is the equation for the variation of m for a series of drain tile of various sizes but of the same material; e and x are constants.

m' =the special values of m found for each series of tile.

Whenever a test is numbered, the reference is to the corresponding numbers in Tables 3 and 4 and to Plates X and XI.

Throughout this discussion the term "concrete tile" is used instead of "cement tile." The American Society for Testing Materials, in its standard specifications for drain tile, defines concrete tile as tile made of "a suitable mixture of Portland cement, mineral aggregates, and water, hardened by hydraulic chemical reaction."

FORMULÆ FOR FLOW OF WATER IN DRAIN TILE.

It is common knowledge that the water enters drains at the joints and not through the walls of the tile. Since there is a joint either every foot or every 2 feet in the length of the drain, water enters the tile drain throughout its entire length. In tile of small sizes, this leads to an appreciable variation in the amount of water carried at different points in the tile; but in the larger sizes the amount entering is so small a proportion of the amount carried as to be unimportant in considering carrying capacity.

The water in any tile drain is caused to flow and velocity is set up by two forces, one due to the grade of the tile line, and the other created when there is a variation in areas of water cross-section.

One authority includes a third force caused by the head due to height of the water table in the soil.

It is interesting to note the variations between the different formulæ recommended for tile drainage. Some formulæ take into account only the grade or slope of the tile drain, while others include the additional head caused by the weight of the water in the soil above the drain. Few formulæ distinguish between the retardation influences in concrete and those in clay drain tile, while many treat both kinds of tile the same.

One formula used by drainage engineers is the well-known Chezy formula,

$$V = C\sqrt{Rs} = CR^{0.5}s^{0.5} \quad (1)$$

This was introduced by Chezy, a French engineer, in 1775. In this formulæ, C is a coefficient, originally considered a constant but since discovered to vary with the retardation factors as well as with the mean hydraulic radius and the slope.

The Kutter modification of the Chezy formula,

$$V = \left\{ \frac{\frac{1.811}{n} + 41.66 + \frac{0.00281}{s}}{1 + \left(41.66 + \frac{0.00281}{s} \right) \frac{n}{\sqrt{R}}} \right\} \sqrt{Rs} \quad (2)$$

is the equation probably most widely used by drainage engineers. To obtain this formula, the coefficient C has been replaced by an expression involving the hydraulic grade or slope and the mean hydraulic radius, as well as a quantity, n , to represent the influence of the roughness of the walls of the channel or conduit.

The Poncelet, Hawkesley,¹ or Eytelwein² formula

$$V = 48 \sqrt{\frac{Dh}{l + 54D}} \quad (3)$$

applies to drains in which the velocity is due only to the hydraulic grade or slope of the drain. It has been used to a great extent for small tile systems in close soil and for determining the size of outlet drains.

According to Wollender, Wage, and John,³ the mean velocity in drain tile is

$$V = 44.2 \sqrt{\frac{Dh}{l + 46.5D}} \quad (4)$$

The Vincent formula is

$$V = 45.95 K \sqrt{\frac{Dh}{l + 50D}} \quad (5)$$

¹ Sullivan's New Hydraulics, p. 9.

² Hamilton Smith's Hydraulics, p. 272.

³ L. Faure, Drainage et Assainissement Agricole des Terres, Paris, 1903, p. 90.

in which Vincent gives values for the variable coefficient, K , ranging from 0.75 for 2-inch tile to 0.875 for 6-inch tile.

Friedrich¹ states that Professor Gieseler's formula,

$$V = 36.22 \sqrt{Ds} \quad (6)$$

is the best in practice as well as the simplest.

Formula 6 is said by Professor Luedecke to have been deduced as early as 1852 by the agricultural engineer Stocken, at Schweidnitz, from Prony's formula, which is

$$V = 47.63 \sqrt{Ds} \quad (7)$$

Beardmore's, sometimes called Leslie's, formula,

$$V = 100 \sqrt{Rs} \quad (8)$$

is similar to Chezy's, the coefficient C being taken as a constant, 100.

The Williams-Hazen general formula for all kinds of pipes is

$$V = C_w R^{0.63} s^{0.54} 0.001^{-0.04} \quad (9)$$

This formula is of special importance in this discussion, since careful comparison of it with the Chezy-Kutter formula has been made.

C. G. Elliott, a widely known drainage authority, has modified the Poncelet or Hawkesley formula as follows:²

$$V = 48 \sqrt{\frac{Dh + \frac{1}{2}U}{l + 54D}} \quad (10)$$

for use on systems where the soil is open;

$$V = 48 \sqrt{\frac{D \left(h + \frac{b}{T} \right)}{l + 54D}} \quad (11)$$

for use on large systems in close soil;

$$V = 48 \sqrt{\frac{D \left(h + \frac{b}{T} \right) + \frac{1}{2}U}{l + 54D}} \quad (12)$$

for use on large systems in open soil.

The last term in the numerator under the radical in formulæ 10 and 12 has been added to allow for the water pressure in the soil above the tile drain. This additional head, however, is constantly varying, being greatest when the earth is completely saturated. It is doubtful whether it should be used in computing the discharge of a drain, and if so, then only in open, porous soils.

¹ Friedrich, Kulturtechnischer Wasserbau, vol. 1, Berlin, 1912, p. 343.

² C. G. Elliott, Engineering for Land Drainage, New York, 2d ed., 1912, p. 93.

A new formula based on tests actually made on drain tile, derived as hereinafter explained, is tentatively offered for tile flowing full. This formula is

$$V = 138 R^{2/3} s^{1/2} \quad (13)$$

It may seem that the exponential type of formula is inconvenient because logarithms must be used to calculate results from it. However, it is comparatively simple in the case of such a formula to prepare a diagram or chart, composed of parallel, straight lines if on logarithmic scale, from which the required velocity or the required discharge for any size of tile at any grade can be obtained at a glance, the accuracy of the reading depending entirely upon the scale of the diagram. Plate XIII is a diagram prepared by using the formula as derived from the actual tests made, but applied to commercial or nominal sizes of tile.

It should be noted that Elliott's modifications of Poncelet's or Hawkesley's formula are the only ones which take into consideration the head caused by the water table in the soil, while the Chezy-Kutter formula is the only one in which the different retardation influences in clay and concrete drain tile may be considered.

NECESSARY DATA FOR COMPARING VELOCITY FORMULÆ.

In order to test the relative accuracy of the various formulæ which have been recommended for use in determining the discharge of tile drains, the effect of each hydraulic element involved in the formulæ must be determined by experiment. However, in the tests made at the experimental plant it was impossible to determine the effect of the additional head caused by the water table in the soil. The elements to be determined are as follows: (1) the mean velocity of the water in the tile drain; (2) the grade or slope of the drain, or the water slope if it is different from that of the drain; (3) the internal size of the tile; (4) the actual depth of flow in the tile drain.

MEAN VELOCITY.

The mean velocity of the water flowing in the drain can be determined by various methods. However, only the following two methods were used: (1) by actually measuring the quantity of water entering or discharging from the tile drain per second, and then solving the equation $V = \frac{Q}{a}$; (2) by timing a given volume of water through a previously measured distance.

HYDRAULIC GRADE OR SLOPE.

The slope of the line of tile tested at the experimental plant was always known, since the tile were laid in an adjustable flume which could be changed to the desired grade, the grade always being checked by a level.

INTERNAL SIZE OF DRAIN TILES.

It is generally known that drain tile are not exactly of the dimensions corresponding to the nominal size. All of the concrete tile used in these experiments were under the nominal size, while the clay tile generally were larger than the nominal size. However, the concrete tile more nearly averaged the nominal size than did the clay tile.

Although in actual practice the nominal or commercial size of tile is invariably used in computing the discharge, yet to determine accurately the retardation factors it is essential to know the correct average diameter of the drain tile being tested. To determine the average diameter of all the tile tested at the experimental plant, two measurements were made at right angles to each other at each end of every tile. This task required the recording and averaging of 1,160 measurements when tile in 2-foot lengths were used, and twice this number when tile in 1-foot lengths were used.

Table 1 gives the dimensions and cross-sectional areas of each kind of tile tested at the experimental plant. From a study of this table several points are revealed. In the first place, considerable error would have been introduced into the final results had the nominal or commercial diameter—instead of the actual, measured, average diameter—been used in the computations. For example, the mean velocity for the 6-inch clay tile at a grade of 0.50 foot in 100 feet, with a depth of flow of 0.498 foot and discharging 0.554 second-foot, is, when computed from the measured average diameter, 2.659 feet per second; with the nominal or commercial diameter the velocity is 2.823 feet per second. As a rule the mean of the areas of the tile computed from the diameters varying most above and below the measured average diameter, with their companion diameters, varies little from the area computed from the measured average diameter.

TABLE 1.—Comparison of dimensions and areas of various kinds of tile used.

1	2	3	4	5	6	7	8	9	10	11	12	13
Kind of tile.	Com- mer- cial size of tile.	Com- mer- cial or nom- inal diam- eter.	Ac- tual meas- ured ave- rage diam- eter.	Area com- puted on col. 3.	Area com- puted on col. 4.	Vari- ation in area be- tween cols. 5 and 6.	Small- est meas- ured diam- eter.	Diam- eter nor- mal to diam- eter in col. 8.	Area ¹ using diam- eters in cols. 8 and 9.	Larg- est meas- ured diam- eter.	Diam- eter nor- mal to diam- eter in col. 11.	Area ¹ using diam- eters in cols. 11 and 12.
	In.	Feet.	Feet.	Sq.ft.	Sq.ft.	P.ct.	Feet.	Feet.	Sq.ft.	Feet.	Feet.	Sq.ft.
Concrete.....	4	0.3333	0.3280	0.0873	0.0845	+3.2	0.3100	0.3300	0.0804	0.3380	0.3320	0.0881
Hard-burned clay.....	4	.3333	.3398	.0873	.0907	-3.9	.3150	.3380	.0837	.3520	.3500	.0968
Concrete.....	5	.4167	.4127	.1364	.1338	+1.9	.3950	.4100	.1272	.4220	.4180	.1385
Hard-burned clay.....	5	.4167	.4193	.1364	.1381	-1.2	.3780	.4510	.1349	.4350	.4310	.1473
Concrete.....	6	.5000	.4970	.1964	.1940	+1.2	.4850	.4850	.1847	.5130	.4950	.1996
Soft-burned clay.....	6	.5000	.5184	.1964	.2111	-7.4	.4760	.5260	.1971	.5350	.5300	.2227
Concrete.....	8	.6667	.6585	.3491	.3406	+2.4	.6400	.6450	.3242	.6770	.6620	.3520
Hard-burned clay.....	8	.6667	.6850	.3491	.3685	-5.5	.6700	.6720	.3536	.7360	.7030	.4066
Concrete.....	10	.8333	.8274	.5454	.5377	+1.4	.8080	.8110	.5147	.8420	.8410	.5562
Vitrified ²	10	.8333	.8360	.5454	.5489	-0.6	.7950	.8300	.5185	.8650	.8400	.5708
Concrete.....	12	1.0000	.9915	.7854	.7721	+1.7	.9630	.9780	.7398	1.0100	1.0000	.7933
Vitrified ²	12	1.0000	.9857	.7854	.7631	+2.8	.9700	.9760	.7436	1.0200	.9980	.7996

¹ Computed as an ellipse.² These tile were in 2-foot lengths; all others in 1-foot lengths.

ACTUAL DEPTH OF FLOW.

The depths of flow in the tile lines tested were measured by means of the 12 piezometer tubes distributed along the flume, as previously described.

As first laid, the tile at the lower end of the experimental line discharged into the open air with a free drop of several inches. This produced a backwater curve of the drop-off type which extended back for a considerable distance into the tile line, decreasing the depth of the water near the lower end. For the steeper slopes this effect was much extended, and, indeed, in extreme cases reached throughout the length of the experimental line. Such a condition was objectionable for two reasons: first, the hydraulic gradient under such circumstances would be represented by the slope of the water surface, which was then somewhat greater than the grade of the tile; second, since the condition was not one of uniform flow, it would become necessary to take account of the change of velocity at different points in the tile, with the corresponding changes in velocity head, in determining the head consumed in overcoming friction. Since these additional complications were unnecessary and objectionable, the drop-off curve was eliminated by installing a low, movable dam (shown in Pl. VIII, fig. 1) just below the lower end of the tile line. By adjusting the height of this dam, the water surface at the outlet could be maintained in close agreement with any desired depth throughout the experimental line.

The water entered the upper end of the tile through a conical entrance pipe (Pl. III, figs. 1 and 2) designed to give an entrance velocity approximating that of the steady, uniform flow in the tile line. But it was found impracticable to adjust the entrance velocity exactly to that of the line, with the result that the upper 50 feet of tile were required to bring the velocity to the condition of uniform flow, and the piezometers at the upper end would not always agree with the others along the tile. With this exception, the readings of depth in the various piezometers along the tile line could generally be brought into satisfactory agreement.

With the tile only partly full, there were occasional quite erratic readings on some piezometers. These indicated unusual disturbances within the tile line. When through the warped or elliptical shape of the tile the joints do not fit closely, a portion of one tile at the joint may project inward in such a way as to present a square obstruction against the edge of the moving stream of water. Violent impact of the water against such an obstruction produces a marked disturbance of the stream, and is indicated by extensive ripples and foam on the water surface which may persist for several feet downstream. Several such cases were carefully examined by uncovering the tile and inspecting the water surface within, as well as by measur-

ing the height of the water surface outside of the tile at the joint. In some cases the water level outside the tile would remain steadily 0.1 or 0.2 foot higher on one side of the tile than on the other, and the surface inside the tile would be very turbulent and would seem to bear no relation to the elevation of the water surface outside the tile joint. Such phenomena were most conspicuous when the depth of flow was between half and full depth, and with the high velocities due to the steeper slopes. The phenomena seemed to depend upon the presence of air in the tile, as they disappeared largely when the tile were completely filled, so that all air was excluded.

METHODS OF CONDUCTING TESTS.

A test was always begun at the least depth of flow. Six men were needed to conduct a complete experiment at one grade, which required from 3 to 6 hours, depending upon the number of depths of flow tested. One man cared for the pump and engine, one read the upper hook gage, a third was stationed midway the length of the flume at a piezometer tube, another was stationed at the outlet to adjust the height of the movable dam, and a fifth man read the lower hook gage. The engineer in charge usually operated the valve controlling the supply of water to the upper weir tank, and watched the upper piezometer tubes.

The engineer announced the depth of flow he desired to obtain to the man stationed at the dam. The gate valve in the supply pipe was partly opened and the piezometer readings noted. The dam was then raised or lowered to secure the correct depth of flow at the piezometer tube near the outlet, special care being taken not to get a greater depth than desired there. The observer at the upper hook gage called out the various gage heights at short intervals, that the water supply might be regulated properly, and when the desired depth in the tile was obtained, sufficient time was allowed to determine that the depth over the weir was constant. The observations at the upper, middle, and lower piezometers indicated when the flow was steady throughout the tile line. When the flow was steady at the proper depth, the signal was given and each of the two hook-gage readers made record of the readings at his station every 30 seconds. Meanwhile, the engineer in charge passed along the flume, recording the readings of all piezometers in succession; the observer at the lower end of the flume went to the upper end and then recorded the piezometer readings in order, following just 2 minutes behind the engineer's readings; the observer at the middle of the flume watched the piezometer there to report if any considerable fluctuation indicated that the test should be run again. If the depth over the upper weir remained constant throughout the test, the engineer proceeded to obtain the next depth of flow; if the weir readings varied, the test

for the same depth of flow was run again. About 20 minutes were required to obtain the data for each depth of flow, the amount of time depending upon the grade of the flume.

The readings for the first two and the last piezometers were not included to obtain the depth of flow in the drain. It should be remembered that water as it enters the drain has not the velocity it will acquire after traveling some distance; therefore the first two piezometers usually recorded a depth slightly different from that of the piezometer 60 feet from the tile entrance or those of the succeeding piezometers. Even with a gradual, conical entrance to the tile drain (Pl. III, figs. 1 and 2), the entrance velocity could not be easily regulated to be the same as the uniform velocity through the main portion of the tile. The average of the readings of the intermediate nine piezometers, less 0.09 foot, usually was taken as the true depth of flow, although at times very erratic individual piezometer readings were obtained which were not used in obtaining the average.

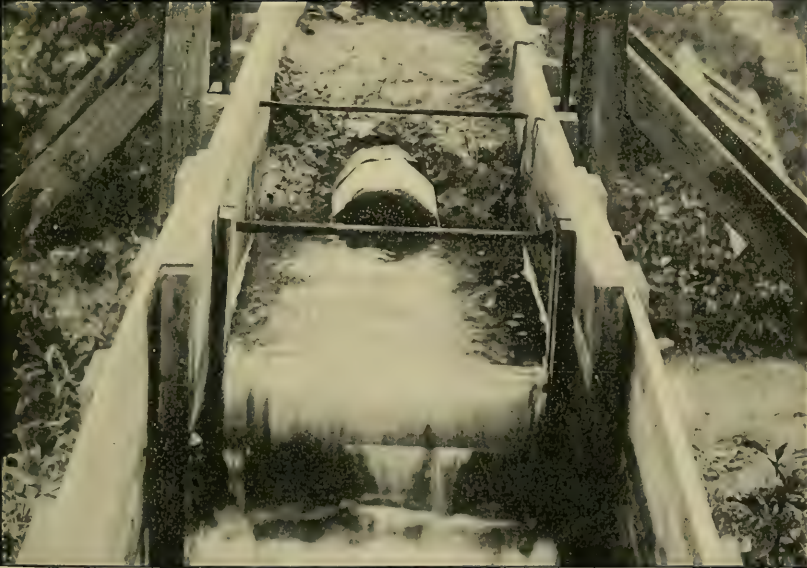
Only the upper weir readings were used in the final computations. It was found in the earlier experiments that after waiting some time for the lower weir box to fill to a steady height, the lower weir would read practically the same as the upper weir, proving that there was no measurable loss of flow in passing through the tile line. Hence, to save time in performing the experiments, it was decided not to wait for the lower weir to reach a steady reading. It may appear that, in using only the upper weir readings to obtain the carrying capacity of the drain, too great a quantity of water was recorded due to seepage into the earth adjacent to the drain, which would credit the tile with carrying more water than it actually did carry. However, observation of the condition of the soil indicated clearly that the soil became sufficiently saturated by the time steady flow was obtained in the tile, that there was no such loss, at least not in quantity that could have affected the results of this investigation.

The use of the dam at the tile outlet did not affect the carrying capacity of the drain, for special care was taken not to allow any piezometer readings at the lower end of the flume to exceed the readings near the upper end. The dam merely assisted in obtaining a uniform depth of flow throughout the length of the drain. Thus the necessity of corrections for changing velocity heads due to decrease in the water cross-sectional area at succeeding piezometers near the outlet was eliminated. Without the dam and with a constant flow over the upper weir, the successive piezometers showed a continuous decrease in depth, and therefore increase in velocity, toward the outlet of the tile line. In other words, the hydraulic gradient or water slope was greater than the grade of the tile. With no change in the amount of water passing over the weir, the height of the dam could be raised until the piezometer near the outlet re-



B. P. R. D-3508

FIG. 2.—12-INCH CLAY TILE AS LAID TO DETERMINE THE EFFECT OF IRREGULAR JOINTS ON THE COEFFICIENT OF ROUGHNESS.



B. P. R. D-3513

FIG. 1.—DAM USED IN EXPERIMENTS TO OBTAIN UNIFORM DEPTH OF FLOW IN TILE.





Y, AND SLOPE.

corded the same depth as that shown by the piezometer 60 feet from the tile entrance, without affecting the latter piezometer but causing the intermediate piezometers to register the same depth.

MEASUREMENT OF MEAN VELOCITY.

As stated before, the mean velocities obtained during the experiments were determined by dividing the quantity of water passing over the upper weir by the average cross-sectional area of the water in the tile. For checking these results, velocities were determined also by coloring matter and by the use of a voltmeter. Both potassium permanganate and dyes were used. For injecting the colored solution into the tile, the use of a large hard-rubber syringe proved a satisfactory method. The voltmeter was of the portable Weston type (model 45) with a range of scale from zero to $1\frac{1}{2}$ volts; carbon and zinc electrodes were used. To complete the circuit, a saturated salt solution was inserted by the method employed in the color tests. When the water saturated with salt passed the point where the electrodes were placed in the tile, a current was set up whose intensity was indicated by the voltmeter. When the volume of saturated water had all passed, the needle of the voltmeter would return to its original position.

An observer noted the time the color was injected and also obtained the times when the first and the last color passed the outlet. The time the color spent in the tile was taken as from the instant of injection to the mean between the first and the last of the appearance at the outlet. This same method was used in the voltmeter tests, the time being taken as from the instant of injection of the salt solution to the mean between the time the needle of the voltmeter began to register and the time when it returned to its original position. Table 2 shows part of the results obtained in comparing the values of the mean velocity as found by the weir, with those determined by color and voltmeter.

TABLE 2.—Comparison of mean velocities as determined by various methods.

Tile diameter.	Velocity by weir (V).	Velocity by color (V _c).	Velocity by voltmeter (V _v).	$\frac{V - V_c}{V}$	$\frac{V - V_v}{V}$
Inches.	Ft. per sec.	Ft. per sec.	Ft. per sec.	Per cent.	Per cent.
4	2.168	2.227	-----	-2.7	-----
4	2.133	2.167	-----	-1.6	-----
4	1.866	1.898	-----	-1.7	-----
12	1.236	1.293	-----	-4.6	-----
12	1.124	1.211	-----	-7.7	-----
12	4.551	4.782	-----	-5.1	-----
12	3.711	3.691	-----	+0.5	-----
12	2.251	2.320	2.291	-3.1	-1.8
12	2.493	2.656	2.500	-6.5	-0.3
12	2.769	2.723	2.764	+1.7	+0.2
12	2.104	2.272	2.235	-8.0	-6.2

For determining the velocity, coloring matter can be used successfully only in clear water. Potassium permanganate as well as dyes of all colors were tried in muddy water having a large velocity and it was found practically impossible to detect the colors. However, the voltmeter method may be used equally well in muddy and in clear water for determining the velocity. It is believed that velocities obtained by the use of either color or voltmeter will be quite accurate if the mean of several readings is taken.

RESULTS OF OBSERVATIONS.

Tables 3, 4, and 5 give the results of the tests. The various series are arranged in ascending sizes of tile and ascending grades. Table 3 gives the results of observations on clay tile; Table 4, the results of observations on concrete tile; and Table 5, the results of observations on clay tile poorly laid. The Kutter coefficient of roughness, n , given in column 10, was determined from a large diagram specially drawn for this investigation. The variation and irregularity of the joints of the tile in the lines poorly laid can be seen in Plate VIII, figure 2.

The tests summarized in Tables 3 and 4 were plotted on coordinate paper, with velocities as abscissæ and depths of flow as ordinates. Mean curves were drawn for each grade through the points representing the tests for each size and kind of tile. These curves are shown on Plate IX. A study of the curves reveals some interesting facts. For the flatter slopes the curves more nearly approximate a straight line; as the slopes increase the lines become more curved, until at the steepest grade there is considerable bulge to the curve. The velocity at any depth of flow over half full is shown at a glance. It will be noted that the velocities at half full and at full are seldom the same, as they would be according to the Chezy formula. The greatest velocity seems to be approximately at the 0.8 depth. The curves were not extended below the half-full point on account of the insufficiency of data. In the largest sizes of tile, where symbols are shown but no curves have been drawn, incompleteness of data has prevented the development of accurate curves through these points. It will be seen that with some of the curves the points lie practically on the lines, while with other curves some points vary greatly, showing probable error in the experiments.

TABLE 3.—*Elements of experiments for clay tile.*

4-INCH TILE.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hydraulic radius.	Discharge.	Velocity.	Slope.	Kutter coefficient.	Chezy coefficient.
	(<i>d</i>)		(<i>a</i>)		(<i>R</i>)	(<i>Q</i>)	(<i>V</i>)	(<i>s</i>)	(<i>n</i>)	(<i>C</i>)
	<i>Feet.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft. per sec.</i>	<i>Feet per sec.</i>			
1 ¹	0.332	0.98	0.0901	0.99	0.0935	0.0547	0.607	0.0005	0.0101	88.8
2 ¹	.309	.91	.0866	.96	.1007	.0562	.649	.0005	.0100	91.4
3.....	.298	.88	.0843	.93	.1023	.0487	.578	.0005	.0110	80.8
4.....	.248	.73	.0709	.78	.1018	.0404	.570	.0005	.0111	79.9
5.....	.214	.63	.0602	.66	.0965	.0274	.456	.0005	.0126	65.6
6.....	.159	.47	.0416	.46	.0813	.0177	.424	.0005	.0120	66.5
7.....	.131	.39	.0322	.36	.0708	.0098	.304	.0005	.0139	51.1
8 ¹	.331	.97	.0900	.99	.0940	.0703	.780	.0010	.0110	80.5
9 ¹	.327	.96	.0896	.99	.0958	.0744	.831	.0010	.0106	84.9
10.....	.285	.84	.0812	.89	.1032	.0580	.714	.0010	.0123	70.3
11.....	.228	.67	.0647	.71	.0992	.0568	.878	.0010	.0104	88.2
12.....	.160	.47	.0420	.46	.0817	.0235	.560	.0010	.0128	62.0
13.....	.136	.40	.0339	.37	.0728	.0166	.490	.0010	.0131	57.4
14 ¹	.329	.97	.0898	.99	.0950	.0969	1.079	.0020	.0113	78.3
15.....	.321	.95	.0887	.98	.0979	.1019	1.148	.0020	.0111	82.1
16.....	.283	.83	.0807	.89	.1033	.0940	1.165	.0020	.0113	81.0
17.....	.271	.80	.0775	.86	.1034	.0904	1.166	.0020	.0112	81.1
18.....	.223	.66	.0631	.70	.0983	.0710	1.125	.0020	.0113	80.2
19.....	.173	.51	.0464	.51	.0859	.0414	.892	.0020	.0122	68.1
20.....	.129	.38	.0316	.35	.0700	.0187	.592	.0020	.0145	50.0
21 ¹	.313	.92	.0874	.96	.1000	.1230	1.408	.0030	.0112	81.3
22.....	.244	.72	.0697	.77	.1013	.0864	1.240	.0030	.0123	71.1
23.....	.213	.63	.0598	.66	.0963	.0685	1.145	.0030	.0127	67.4
24.....	.166	.49	.0440	.49	.0837	.0361	.820	.0030	.0148	51.8
25.....	.123	.36	.0296	.33	.0675	.0180	.608	.0030	.0161	42.7
26 ¹	.317	.93	.0881	.97	.0990	.1578	1.792	.0050	.0113	80.5
27.....	.287	.84	.0817	.90	.1032	.1494	1.829	.0050	.0114	80.5
28.....	.263	.77	.0753	.83	.1031	.1327	1.762	.0050	.0117	77.6
29.....	.223	.66	.0631	.70	.0983	.0978	1.550	.0050	.0125	69.9
30.....	.170	.50	.0454	.50	.0850	.0517	1.139	.0050	.0142	55.3
31.....	.128	.38	.0313	.35	.0696	.0256	.819	.0050	.0159	43.9
32 ¹	.332	.98	.0901	.99	.0935	.1931	2.142	.0075	.0111	80.9
33 ¹	.320	.94	.0886	.98	.0982	.1905	2.151	.0075	.0114	79.3
34.....	.288	.85	.0819	.90	.1031	.1756	2.143	.0075	.0118	77.1
35.....	.253	.74	.0724	.80	.1023	.1482	2.047	.0075	.0121	73.9
36.....	.209	.62	.0585	.65	.0954	.0996	1.702	.0075	.0133	63.6
37.....	.164	.48	.0434	.48	.0830	.0654	1.508	.0075	.0133	60.4
38.....	.134	.39	.0332	.37	.0720	.0425	1.279	.0075	.0137	55.0
39 ¹	.312	.92	.0872	.96	.1002	.2159	2.477	.0100	.0116	78.3
40.....	.298	.88	.0843	.93	.1023	.2068	2.453	.0100	.0118	76.7
41.....	.283	.83	.0807	.89	.1033	.1984	2.459	.0100	.0118	76.5
42.....	.233	.69	.0663	.73	.1000	.1476	2.227	.0100	.0125	70.4
43.....	.205	.60	.0572	.63	.0946	.1140	1.994	.0100	.0131	64.8
44.....	.151	.44	.0389	.43	.0785	.0615	1.579	.0100	.0138	56.4
45 ¹	.331	.97	.0900	.99	.0940	.2640	2.932	.0125	.0107	85.5
46.....	.304	.90	.0856	.94	.1016	.2472	2.888	.0125	.0113	81.1
47.....	.270	.80	.0773	.85	.1033	.2124	2.749	.0125	.0120	76.5
48.....	.254	.75	.0727	.80	.1024	.1951	2.683	.0125	.0120	75.0
49.....	.177	.52	.0478	.53	.0871	.1032	2.161	.0125	.0127	65.5
50.....	.148	.44	.0379	.42	.0774	.0736	1.941	.0125	.0128	62.4
51 ¹	.329	.97	.0898	.99	.0950	.2890	3.218	.0150	.0108	85.3
52 ¹	.313	.92	.0874	.96	.1000	.2907	3.328	.0150	.0108	85.9
53.....	.298	.88	.0843	.93	.1023	.2814	3.338	.0150	.0110	85.2
54.....	.257	.76	.0736	.81	.1027	.2318	3.150	.0150	.0114	80.2
55.....	.228	.67	.0647	.71	.0992	.2026	3.132	.0150	.0113	81.2
56.....	.168	.49	.0447	.49	.0843	.1322	2.957	.0150	.0107	83.1
57.....	.126	.37	.0306	.34	.0688	.0720	2.353	.0150	.0111	73.3

5-INCH TILE.

58 ¹	0.404	0.96	0.1364	0.99	0.1180	0.0868	0.636	0.0005	0.0111	82.8
59 ¹	.390	.93	.1338	.97	.1225	.0848	.634	.0005	.0114	81.0
60.....	.350	.83	.1231	.89	.1275	.0832	.676	.0005	.0112	84.6

¹ These tests used in deriving formulæ 27 and 29.

TABLE 3.—*Elements of experiments for clay tile—Continued.*

5-INCH TILE—Continued.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hydraulic radius.	Discharge.	Velocity.	Slope.	Kutter coefficient.	Chezy coefficient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
	<i>Fect.</i>		<i>Sq. ft.</i>		<i>Fect.</i>	<i>Cu. ft. per sec.</i>	<i>Fect. per sec.</i>			
61.....	0.314	0.75	0.1109	0.80	0.1265	0.0699	0.630	0.0005	0.0116	79.3
62.....	.255	.61	.0879	.64	.1171	.0547	.623	.0005	.0113	81.3
63.....	.221	.53	.0738	.54	.1083	.0386	.523	.0005	.0122	71.1
64.....	.162	.39	.0492	.36	.0875	.0150	.305	.0005	.0157	46.2
65.....	.119	.28	.0323	.23	.0684	.0074	.231	.0005	.0165	39.4
66 ¹	.406	.97	.1368	.99	.1172	.1415	1.035	.0010	.0102	95.6
67 ¹	.402	.96	.1361	.99	.1189	.1366	1.003	.0010	.0105	92.0
68.....	.390	.83	.1231	.89	.1275	.1230	.999	.0010	.0110	88.5
69.....	.314	.75	.1109	.80	.1264	.1065	.960	.0010	.0112	85.4
70.....	.273	.65	.0952	.69	.1209	.0824	.866	.0010	.0118	78.7
71.....	.215	.51	.0713	.52	.1065	.0532	.746	.0010	.0122	72.3
72.....	.155	.37	.0464	.34	.0847	.0231	.497	.0010	.0142	54.0
73.....	.116	.28	.0311	.23	.0670	.0165	.531	.0010	.0119	64.9
74 ¹	.411	.98	.1374	.99	.1146	.1905	1.386	.0020	.0105	91.6
75 ¹	.410	.98	.1373	.99	.1152	.1892	1.378	.0020	.0106	90.8
76.....	.348	.83	.1225	.89	.1275	.1827	1.491	.0020	.0106	93.4
77.....	.315	.75	.1113	.81	.1265	.1686	1.515	.0020	.0105	95.3
78.....	.279	.67	.0976	.71	.1220	.1371	1.405	.0020	.0108	90.0
79.....	.212	.51	.0700	.51	.1056	.0840	1.200	.0020	.0112	82.6
80.....	.164	.39	.0501	.36	.0883	.0481	.961	.0020	.0118	72.3
81.....	.129	.31	.0361	.26	.0732	.0291	.807	.0020	.0120	66.7
82 ¹	.399	.95	.1356	.98	.1199	.2408	1.775	.0030	.0105	93.6
83 ¹	.392	.94	.1343	.97	.1220	.2370	1.765	.0030	.0106	92.3
84.....	.352	.84	.1238	.90	.1274	.2208	1.784	.0030	.0108	91.3
85.....	.321	.77	.1134	.82	.1270	.1998	1.761	.0030	.0109	90.3
86.....	.273	.65	.0952	.69	.1209	.1566	1.645	.0030	.0111	86.4
87.....	.219	.52	.0730	.53	.1077	.0987	1.368	.0030	.0119	76.4
88.....	.165	.39	.0505	.37	.0887	.0544	1.078	.0030	.0126	66.1
89.....	.115	.27	.0308	.22	.0665	.0231	.751	.0030	.0137	53.1
90 ¹	.397	.95	.1352	.98	.1205	.3026	2.237	.0050	.0107	91.1
91.....	.377	.90	.1308	.95	.1250	.3096	2.367	.0050	.0106	94.7
92.....	.347	.83	.1222	.89	.1275	.2958	2.421	.0050	.0105	95.9
93.....	.298	.71	.1050	.76	.1247	.2464	2.347	.0050	.0106	94.0
94.....	.254	.61	.0875	.63	.1169	.1892	2.162	.0050	.0109	89.4
95.....	.220	.52	.0734	.53	.1080	.1448	1.973	.0050	.0111	84.9
96.....	.154	.37	.0460	.33	.0842	.0784	1.705	.0050	.0107	83.1
97.....	.118	.28	.0319	.23	.0680	.0381	1.194	.0050	.0121	64.8
98 ¹	.387	.92	.1332	.97	.1232	.3573	2.682	.0075	.0111	88.2
99 ¹	.383	.91	.1423	.96	.1240	.3582	2.708	.0075	.0110	88.8
100.....	.325	.78	.1148	.83	.1272	.3326	2.896	.0075	.0107	93.7
101.....	.281	.67	.0984	.71	.1223	.2746	2.790	.0075	.0107	92.1
102.....	.249	.59	.0855	.62	.1158	.2215	2.592	.0075	.0110	88.0
103.....	.197	.47	.0637	.46	.1006	.1404	2.203	.0075	.0114	80.2
104.....	.142	.34	.0412	.30	.0791	.0816	1.981	.0075	.0108	81.4
105.....	.118	.28	.0319	.23	.0680	.0445	1.396	.0075	.0126	61.8
106 ¹	.402	.96	.1361	.99	.1189	.4009	2.945	.0100	.0113	85.4
107 ¹	.383	.91	.1323	.96	.1240	.4051	3.063	.0100	.0112	87.0
108.....	.326	.78	.1152	.83	.1273	.3740	3.247	.0100	.0109	91.0
109.....	.282	.67	.0988	.72	.1225	.3096	3.135	.0100	.0110	89.6
110.....	.252	.60	.0867	.63	.1165	.2648	3.055	.0100	.0109	89.5
111.....	.216	.52	.0717	.52	.1068	.2096	2.923	.0100	.0107	89.4
112.....	.154	.37	.0460	.33	.0842	.1255	2.730	.0100	.0098	94.1
113.....	.111	.26	.0293	.21	.0646	.0640	2.185	.0100	.0098	86.6
114 ¹	.402	.96	.1361	.99	.1189	.4749	3.488	.0125	.0108	90.5
115 ¹	.386	.92	.1330	.96	.1234	.4703	3.537	.0125	.0109	90.1
116.....	.327	.78	.1155	.84	.1273	.4272	3.698	.0125	.0107	92.7
117.....	.294	.70	.1034	.75	.1242	.3862	3.734	.0125	.0105	94.7
118.....	.264	.63	.0916	.66	.1190	.3392	3.704	.0125	.0103	96.0
119.....	.221	.53	.0738	.53	.1083	.2624	3.556	.0125	.0101	96.7
120.....	.173	.41	.0588	.39	.0919	.1698	3.158	.0125	.0100	93.2
121.....	.115	.27	.0308	.22	.0665	.0836	2.718	.0125	.0092	94.3
122. ¹	.399	.95	.1356	.98	.1199	.5415	3.993	.0150	.0105	94.2
123. ¹	.394	.94	.1347	.98	.1215	.5428	4.030	.0150	.0105	94.4
124.....	.343	.82	.1209	.88	.1276	.5066	4.190	.0150	.0105	95.8
125.....	.319	.76	.1127	.82	.1269	.4738	4.203	.0150	.0104	96.4
126.....	.253	.60	.0871	.63	.1167	.3582	4.113	.0150	.0102	98.3
127.....	.209	.50	.0688	.50	.1046	.2704	3.932	.0150	.0099	99.3
128.....	.158	.38	.0476	.35	.0859	.1674	3.516	.0150	.0095	98.0
129.....	.118	.28	.0319	.23	.0680	.0969	3.041	.0150	.0093	95.2

¹ These tests used in deriving formulæ 27 and 29.

TABLE 3.—*Elements of experiments for clay tile—Continued.*

6-INCH TILE.

1 Test No.	2 Depth of flow. (<i>d</i>)	3 $\frac{d}{D}$	4 Area of flow. (<i>a</i>)	5 $\frac{a}{A}$	6 Hydraulic radius. (<i>R</i>)	7 Discharge. (<i>Q</i>)	8 Velocity. (<i>V</i>)	9 Slope. (<i>s</i>)	10 Kutter coefficient. (<i>n</i>)	11 Chezy coefficient. (<i>C</i>)
	<i>Feet.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft. per sec.</i>	<i>Feet per sec.</i>			
130 ¹	0.517	1.00	0.2110	1.00	0.1319	0.1614	0.765	0.0005	0.0103	94.2
131	.402	.78	.1756	.83	.1573	.1404	.800	.0005	.0111	90.1
132	.300	.58	.1266	.60	.1412	.0724	.572	.0005	.0134	68.0
133	.223	.43	.0868	.41	.1170	.0397	.457	.0005	.0141	59.7
134	.188	.36	.0692	.33	.1031	.0225	.325	.0005	.0165	45.3
13	.510	.98	.2103	.99	.1404	.2229	1.060	.0010	.0111	89.5
136	.396	.76	.1730	.82	.1569	.1578	.912	.0010	.0132	72.8
137	.304	.59	.1286	.61	.1422	.1255	.976	.0010	.0119	81.8
138	.221	.43	.0858	.41	.1163	.0706	.823	.0010	.0120	76.3
139	.171	.33	.0607	.29	.0958	.0372	.613	.0010	.0132	62.6
140 ¹	.498	.96	.2083	.99	.1465	.3563	1.710	.0020	.0104	99.9
141	.409	.79	.1786	.85	.1576	.2680	1.500	.0020	.0119	84.5
142	.277	.53	.1148	.54	.1350	.1801	1.569	.0020	.0105	95.5
143	.216	.42	.0832	.39	.1144	.1090	1.310	.0020	.0110	86.6
144	.157	.30	.0540	.26	.0893	.0559	1.036	.0020	.0112	77.5
145 ¹	.508	.98	.2100	.99	.1418	.4282	2.039	.0030	.0104	98.8
146	.414	.80	.1807	.86	.1577	.3620	2.003	.0030	.0112	92.1
147	.302	.58	.1276	.61	.1417	.2194	1.719	.0030	.0118	83.4
148	.222	.43	.0863	.41	.1167	.1382	1.601	.0030	.0112	85.6
149	.167	.32	.0588	.28	.0939	.0685	1.165	.0030	.0123	69.4
150 ¹	.498	.96	.2083	.99	.1465	.5540	2.659	.0050	.0106	98.2
151	.378	.73	.1649	.78	.1552	.4440	2.692	.0050	.0108	96.6
152	.276	.53	.1143	.54	.1347	.2771	2.425	.0050	.0108	93.5
153	.213	.41	.0817	.39	.1133	.1512	1.850	.0050	.0119	77.7
154	.152	.29	.0516	.24	.0870	.0664	1.287	.0050	.0131	61.7
155 ¹	.473	.91	.2020	.96	.1534	.6804	3.368	.0075	.0106	99.3
156	.385	.74	.1681	.80	.1560	.5390	3.206	.0075	.0111	93.7
157	.258	.50	.1049	.50	.1292	.2771	2.641	.0075	.0115	84.9
158	.199	.38	.0746	.35	.1077	.1692	2.268	.0075	.0116	79.8
159	.147	.28	.0493	.23	.0846	.0969	1.967	.0075	.0112	78.1
160	.461	.89	.1983	.94	.1554	.7630	3.847	.0100	.0107	97.6
161	.336	.65	.1448	.69	.1491	.5174	3.575	.0100	.0111	92.6
162	.222	.43	.0863	.41	.1167	.2560	2.966	.0100	.0111	86.8
163	.191	.37	.0706	.33	.1044	.1608	2.278	.0100	.0126	70.5
164	.141	.27	.0465	.22	.0817	.0864	1.860	.0100	.0126	65.1
165	.405	.78	.1769	.84	.1574	.8028	4.538	.0125	.0104	102.3
166	.343	.66	.1482	.70	.1505	.6346	4.281	.0125	.0106	98.7
167	.260	.50	.1060	.50	.1299	.3894	3.674	.0125	.0109	91.2
168	.204	.39	.0771	.37	.1097	.2600	3.371	.0125	.0105	91.0
169	.147	.28	.0492	.23	.0846	.1185	2.409	.0125	.0116	74.1
170	.392	.76	.1712	.81	.1567	.8771	5.122	.0150	.0102	105.7
171	.333	.64	.1433	.68	.1485	.6650	4.641	.0150	.0106	98.3
172	.233	.45	.0920	.44	.1207	.3592	3.904	.0150	.0107	91.7
173	.175	.34	.0627	.30	.0975	.2243	3.579	.0150	.0101	93.6
174	.140	.27	.0460	.22	.0812	.0872	1.896	.0150	.0142	54.3

8-INCH TILE.

175 ¹	0.673	0.98	0.3670	0.99	0.1862	0.3240	0.883	0.0005	0.0114	91.5
176 ¹	.664	.97	.3652	.99	.1911	.3260	.893	.0005	.0115	91.3
177	.615	.75	.2972	.81	.2067	.2540	.885	.0005	.0122	84.1
178	.342	.50	.1839	.50	.1711	.1370	.745	.0005	.0123	80.6
179	.259	.38	.1277	.35	.1406	.0840	.658	.0005	.0120	78.5
180	.166	.24	.0689	.19	.0978	.0363	.527	.0005	.0114	75.4
181 ¹	.656	.96	.3631	.99	.1944	.4570	1.259	.0010	.0118	90.3
182 ¹	.656	.96	.3631	.99	.1944	.4670	1.286	.0010	.0116	92.2
183	.509	.74	.2936	.80	.2061	.3740	1.274	.0010	.0121	88.7
184	.348	.51	.1881	.51	.1730	.2060	1.095	.0010	.0122	83.3
185	.271	.40	.1357	.37	.1456	.1380	1.017	.0010	.0118	84.4
186	.192	.28	.0846	.23	.1106	.0720	.851	.0010	.0114	80.9

¹ These tests used in deriving formulæ 27 and 29.

TABLE 3.—*Elements of experiments for clay tile—Continued.*

8-INCH TILE—Continued.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hy- draulic radius.	Dis- charge.	Ve- locity.	Slope.	Kutter coeff- icient.	Chezy coeff- icient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
	<i>Feet.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft. per sec.</i>	<i>Feet per sec.</i>			
187 ¹	0.669	0.98	0.3663	0.99	0.1885	0.6750	1.842	0.0020	0.0113	94.9
188 ¹	.661	.96	.3644	.99	.1924	.6720	1.844	.0020	.0115	94.0
189.....	.509	.74	.2936	.80	.2061	.5220	1.778	.0020	.0123	87.6
190.....	.358	.52	.1949	.53	.1760	.2805	1.439	.0020	.0130	76.8
191.....	.267	.39	.1329	.36	.1439	.1540	1.159	.0020	.0138	68.4
192.....	.165	.24	.0684	.19	.0973	.0540	.790	.0020	.0144	56.6
193 ¹	.670	.98	.3664	.99	.1880	.7996	2.182	.0030	.0117	91.9
194.....	.663	.97	.3649	.99	.1915	.7870	2.157	.0030	.0119	90.1
195.....	.510	.74	.2942	.80	.2062	.6390	2.172	.0030	.0122	87.5
196.....	.364	.53	.1990	.54	.1778	.3392	1.705	.0030	.0136	73.8
197.....	.280	.41	.1417	.39	.1490	.2054	1.449	.0030	.0139	68.7
198.....	.196	.29	.0871	.24	.1126	.0920	1.057	.0030	.0149	57.6
199 ¹	.676	.99	.3675	.99	.1840	1.0800	2.939	.0050	.0112	96.9
200.....	.558	.82	.3215	.87	.2085	.9210	2.870	.0050	.0121	88.9
201.....	.427	.62	.2415	.66	.1935	.5660	2.344	.0050	.0137	75.4
202.....	.358	.52	.1949	.53	.1760	.3950	2.030	.0050	.0143	68.4
203.....	.272	.40	.1363	.37	.1459	.2360	1.730	.0050	.0145	64.0
204.....	.177	.26	.0755	.21	.1033	.0946	1.250	.0050	.0149	55.0
205 ¹	.662	.97	.3647	.99	.1919	1.2840	3.522	.0075	.0117	92.8
206 ¹	.642	.94	.3588	.97	.1989	1.3000	3.623	.0075	.0117	93.8
207.....	.503	.73	.2900	.79	.2055	.9480	3.270	.0075	.0129	83.3
208.....	.356	.52	.1935	.53	.1754	.5590	2.889	.0075	.0128	79.7
209.....	.270	.39	.1350	.37	.1451	.3392	2.513	.0075	.0127	76.2
210.....	.180	.26	.0773	.21	.1048	.1481	1.915	.0075	.0129	68.3
211 ¹	.667	.97	.3658	.99	.1886	1.4920	4.079	.010	.0116	93.7
212 ¹	.661	.96	.3644	.99	.1924	1.4650	4.021	.010	.0118	91.7
213 ¹	.657	.96	.3635	.99	.1940	1.4475	3.982	.010	.0120	90.4
214.....	.473	.69	.2714	.74	.2021	1.1580	4.267	.010	.0116	94.9
215.....	.325	.47	.1723	.47	.1654	.5980	3.471	.010	.0120	85.4
216.....	.250	.37	.1217	.33	.1369	.3760	3.089	.010	.0118	83.5
217.....	.173	.25	.0731	.20	.1013	.1814	2.483	.010	.0116	78.0
218 ¹	.673	.98	.3670	.99	.1861	1.6200	4.414	.0125	.0118	91.5
219 ¹	.669	.98	.3663	.99	.1885	1.6200	4.423	.0125	.0118	91.1
220.....	.490	.72	.2821	.77	.2040	1.3475	4.778	.0125	.0117	94.6
221.....	.346	.51	.1867	.51	.1723	.7525	4.031	.0125	.0120	86.9
222.....	.260	.38	.1283	.35	.1410	.4430	3.453	.0125	.0120	82.3
223.....	.173	.25	.0731	.20	.1013	.2096	2.869	.0125	.0113	80.6
224.....	.553	.81	.3187	.87	.2085	1.7675	5.546	.0150	.0112	99.2
225.....	.540	.79	.3116	.85	.2082	1.7375	5.576	.0150	.0111	99.8
226.....	.501	.73	.2888	.78	.2053	1.5350	5.316	.0150	.0114	95.8
227.....	.338	.49	.1812	.49	.1698	.7932	4.378	.0150	.0119	86.7
228.....	.256	.37	.1257	.34	.1394	.4772	3.798	.0150	.0119	83.1
229.....	.166	.24	.0689	.19	.0978	.2138	3.102	.0150	.0112	81.0

10-INCH TILE.

230 ¹	0.821	0.98	0.5467	0.99	0.2275	0.6386	1.168	0.0005	0.0104	109.5
231 ¹	.812	.97	.5444	.99	.2324	.5874	1.079	.0005	.0112	100.1
232 ¹	.783	.94	.5343	.97	.2429	.5770	1.080	.0005	.0114	98.0
233.....	.749	.90	.5186	.95	.2497	.5640	1.088	.0005	.0116	97.3
234.....	.697	.83	.4890	.89	.2541	.5578	1.141	.0005	.0112	101.2
235.....	.666	.80	.4689	.85	.2542	.5503	1.174	.0005	.0110	104.1
236.....	.626	.75	.4408	.80	.2521	.5366	1.217	.0005	.0107	108.4
237.....	.567	.68	.3963	.72	.2451	.4982	1.257	.0005	.0102	113.6
238.....	.546	.65	.3798	.69	.2413	.4611	1.214	.0005	.0104	110.8
239.....	.473	.57	.3203	.58	.2250	.3967	1.239	.0005	.0098	116.5
240.....	.421	.50	.2770	.50	.2099	.3078	1.111	.0005	.0103	108.4
241.....	.310	.37	.1852	.34	.1692	.1995	1.079	.0005	.0093	117.3
242.....	.214	.26	.1110	.20	.1251	.1005	.906	.0005	.0089	114.5

¹ These tests used in deriving formulæ 27 and 29.

TABLE 3.—*Elements of experiments for clay tile—Continued.*

10-INCH TILE—Continued.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hy- draulic radius.	Dis- charge.	Ve- locity.	Slope.	Kutter coeff- icient.	Chezy coeff- icient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
	Feet.		Sq. ft.		Feet.	Cu. ft. per sec.	Feet per sec.			
243 ¹	0.782	0.94	0.5339	0.97	0.2431	0.8870	1.661	0.0010	0.0109	106.6
244	.723	.87	.5045	.92	.2526	.8837	1.752	.0010	.0107	110.2
245	.681	.82	.4788	.87	.2544	.8722	1.822	.0010	.0104	114.2
246	.625	.75	.4401	.80	.2520	.7996	1.817	.0010	.0103	114.5
247	.572	.68	.4002	.73	.2459	.7120	1.780	.0010	.0104	113.5
248	.542	.65	.3766	.69	.2406	.6748	1.792	.0010	.0102	115.6
249	.466	.56	.3145	.57	.2231	.5378	1.710	.0010	.0101	114.5
250	.425	.51	.2803	.51	.2112	.4726	1.686	.0010	.0099	116.1
251	.313	.37	.1876	.34	.1704	.2788	1.486	.0010	.0097	113.8
252	.205	.25	.1044	.19	.1206	.1240	1.188	.0010	.0094	108.2
253 ¹	.823	.99	.5471	.99	.2260	1.2680	2.318	.0020	.0106	109.0
254 ¹	.797	.95	.5397	.98	.2385	1.2680	2.350	.0020	.0108	107.6
255 ¹	.778	.93	.5322	.97	.2441	1.2520	2.353	.0020	.0110	106.5
256	.694	.83	.4871	.89	.2542	1.2300	2.525	.0020	.0106	112.0
257	.667	.80	.4696	.86	.2543	1.1840	2.521	.0020	.0106	111.8
258	.623	.75	.4386	.80	.2518	1.1380	2.595	.0020	.0104	115.6
259	.563	.67	.3932	.72	.2444	1.0090	2.566	.0020	.0102	116.1
260	.525	.63	.3629	.66	.2370	.9380	2.585	.0020	.0100	118.8
261	.472	.56	.3195	.58	.2248	.7964	2.493	.0020	.0100	117.6
262	.428	.51	.2828	.52	.2121	.6832	2.416	.0020	.0099	117.3
263	.318	.38	.1917	.35	.1724	.3841	2.004	.0020	.0101	107.9
264	.203	.24	.1030	.19	.1196	.1614	1.567	.0020	.0099	101.4
265 ¹	.827	.99	.5479	.99	.2232	1.5300	2.793	.0030	.0107	107.9
266 ¹	.814	.97	.5449	.99	.2314	1.5350	2.817	.0030	.0109	106.9
267	.810	.97	.5438	.99	.2334	1.5350	2.823	.0030	.0109	106.7
268 ¹	.804	.96	.5421	.99	.2360	1.5250	2.813	.0030	.0110	105.8
269 ¹	.796	.95	.5393	.98	.2388	1.5180	2.815	.0030	.0111	105.2
270	.777	.93	.5318	.97	.2444	1.5140	2.847	.0030	.0111	105.1
271	.756	.90	.5221	.95	.2485	1.5020	2.877	.0030	.0112	105.4
272	.689	.82	.4840	.88	.2543	1.4960	3.091	.0030	.0107	111.9
273	.684	.82	.4808	.88	.2544	1.4800	3.078	.0030	.0107	111.4
274	.631	.76	.4444	.81	.2525	1.3960	3.141	.0030	.0105	114.1
275	.563	.67	.3932	.72	.2444	1.2100	3.077	.0030	.0104	113.7
276	.542	.65	.3766	.69	.2406	1.1240	2.985	.0030	.0106	111.1
277	.484	.58	.3294	.60	.2278	.9227	2.801	.0030	.0108	107.2
278	.431	.52	.2853	.52	.2130	.7450	2.611	.0030	.0110	103.3
279	.328	.39	.1998	.36	.1765	.4542	2.274	.0030	.0109	98.8
280	.224	.27	.1183	.22	.1301	.2173	1.836	.0030	.0107	93.0
281 ¹	.801	.96	.5410	.99	.2371	1.9900	3.678	.0050	.0110	106.8
282 ¹	.801	.96	.5410	.99	.2371	1.9700	3.641	.0050	.0110	105.8
283	.751	.90	.5197	.95	.2494	1.9575	3.767	.0050	.0110	106.7
284	.701	.84	.4915	.90	.2540	1.9300	3.927	.0050	.0108	110.2
285	.665	.80	.4682	.85	.2542	1.8400	3.930	.0050	.0108	110.2
286	.647	.77	.4558	.83	.2536	1.7975	3.944	.0050	.0107	110.7
287	.618	.74	.4350	.79	.2512	1.6575	3.811	.0050	.0110	107.5
288	.565	.68	.3948	.72	.2448	1.4700	3.724	.0050	.0110	106.5
289	.534	.64	.3701	.67	.2389	1.3625	3.681	.0050	.0110	106.5
290	.470	.56	.3178	.58	.2242	1.0980	3.455	.0050	.0111	103.2
291	.426	.51	.2811	.51	.2115	.9261	3.294	.0050	.0112	101.3
292	.307	.37	.1828	.33	.1679	.5306	2.903	.0050	.0107	108.2
293	.213	.25	.1102	.20	.1246	.2568	2.330	.0050	.0106	93.3
294 ¹	.801	.96	.5410	.99	.2371	2.3850	4.409	.0075	.0111	104.5
295 ¹	.796	.95	.5393	.98	.2388	2.4120	4.473	.0075	.0110	105.7
296	.782	.94	.5339	.97	.2431	2.3700	4.450	.0075	.0112	104.2
297	.748	.90	.5181	.94	.2498	2.3700	4.586	.0075	.0111	106.0
298	.726	.87	.5063	.92	.2524	2.3400	4.623	.0075	.0111	106.3
299	.684	.82	.4808	.88	.2544	2.2590	4.699	.0075	.0110	107.6
300	.646	.77	.4551	.83	.2536	2.1330	4.687	.0075	.0110	107.5
301	.564	.68	.3939	.72	.2446	1.8150	4.608	.0075	.0109	107.6
302	.540	.65	.3749	.68	.2401	1.6925	4.515	.0075	.0110	106.4
303	.487	.58	.3318	.61	.2286	1.4350	4.325	.0075	.0110	104.5
304	.409	.49	.2669	.49	.2060	1.0820	4.054	.0075	.0109	103.1
305	.311	.37	.1860	.34	.1696	.6440	3.462	.0075	.0110	97.9
306	.226	.27	.1198	.22	.1311	.3449	2.879	.0075	.0109	91.1

¹ These tests used in deriving formulæ 27 and 29.

TABLE 3.—*Elements of experiments for clay tile—Continued.*

10-INCH TILE—Continued.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hydraulic radius.	Discharge.	Velocity.	Slope.	Kutter coefficient.	Chezy coefficient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
	<i>Feet.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft. per sec.</i>	<i>Feet per sec.</i>			
307 ¹	.809	0.97	0.5435	0.99	0.2338	2.7715	5.099	0.0100	0.0110	105.5
308 ¹	.795	.95	.5389	.98	.2391	2.7645	5.130	.0075	.0111	105.0
309	.744	.89	.5161	.94	.2505	2.7070	5.245	.0100	.0112	104.8
310	.741	.89	.5145	.94	.2508	2.7505	5.347	.0100	.0111	106.8
311	.708	.85	.4957	.90	.2537	2.6695	5.385	.0100	.0111	106.9
312	.705	.84	.4939	.90	.2538	2.6485	5.363	.0100	.0111	106.4
313	.676	.81	.4755	.87	.2545	2.5980	5.464	.0100	.0110	108.3
314	.642	.77	.4523	.82	.2534	2.5050	5.538	.0100	.0108	110.0
315	.577	.69	.4041	.74	.2466	2.1960	5.435	.0100	.0108	109.5
316	.545	.65	.3790	.69	.2411	2.0075	5.297	.0100	.0109	107.9
317	.489	.59	.3335	.61	.2291	1.7325	5.196	.0100	.0107	108.6
318	.414	.50	.2711	.49	.2077	1.2920	4.766	.0100	.0108	104.6
319	.299	.36	.1764	.32	.1645	.7270	4.122	.0100	.0106	101.6
320	.212	.25	.1095	.20	.1241	.3831	3.498	.0100	.0102	99.3
321 ¹	.819	.98	.5462	.99	.2288	3.1220	5.717	.0125	.0109	106.9
322	.752	.90	.5202	.95	.2492	3.0380	5.841	.0125	.0112	104.7
323	.697	.83	.4890	.89	.2541	2.9750	6.085	.0125	.0110	107.9
324	.657	.79	.4628	.84	.2541	2.8430	6.144	.0125	.0109	109.0
325	.636	.76	.4480	.82	.2529	2.7715	6.187	.0125	.0109	110.0
326	.563	.67	.3932	.72	.2444	2.4030	6.112	.0125	.0107	110.6
327	.528	.63	.3653	.67	.2376	2.2080	6.045	.0125	.0106	110.9
328	.461	.55	.3104	.57	.2218	1.7950	5.784	.0125	.0106	109.8
329	.418	.50	.2745	.50	.2090	1.5120	5.509	.0125	.0106	107.8
330	.308	.37	.1836	.34	.1683	.8804	4.796	.0125	.0104	104.5
331	.208	.25	.1066	.19	.1221	.4303	4.038	.0125	.0099	103.4
332	.618	.74	.4350	.79	.2512	2.8580	6.569	.0150	.0110	107.0
333	.557	.67	.3885	.71	.2433	2.5380	6.533	.0150	.0109	108.1
334	.526	.63	.3637	.66	.2372	2.3670	6.509	.0150	.0108	109.1
335	.457	.55	.3070	.56	.2206	1.8480	6.018	.0150	.0110	104.6
336	.392	.47	.2527	.46	.2003	1.4120	5.587	.0150	.0110	101.9
337	.300	.36	.1772	.32	.1650	.8854	4.997	.0150	.0107	100.5
338	.215	.26	.1117	.20	.1256	.4462	3.995	.0150	.0108	92.0

12-INCH TILE.

339 ¹	0.986	1.00	0.7631	1.00	0.2464	0.8972	1.176	0.0005	0.0108	105.9
340 ¹	.896	.91	.7286	.96	.2922	.9006	1.236	.0005	.0115	102.3
341	.856	.87	.7037	.92	.2975	.8540	1.214	.0005	.0118	99.5
342	.803	.81	.6657	.87	.3000	.8380	1.259	.0005	.0115	102.8
343	.754	.76	.6263	.82	.2985	.7360	1.175	.0005	.0121	96.2
344	.694	.70	.5743	.75	.2924	.6762	1.178	.0005	.0120	97.4
345	.650	.66	.5338	.70	.2857	.6496	1.217	.0005	.0115	101.8
346	.592	.60	.4786	.63	.2738	.5390	1.126	.0005	.0119	96.3
347	.558	.57	.4456	.58	.2654	.5006	1.124	.0005	.0117	97.6
348	.502	.51	.3906	.51	.2493	.4261	1.091	.0005	.0115	97.7
349	.412	.42	.3022	.40	.2181	.2754	.911	.0005	.0122	87.3
350	.306	.31	.2019	.27	.1732	.1518	.752	.0005	.0124	80.8
351 ¹	.931	.95	.7464	.98	.2841	1.4350	1.923	.0010	.0107	114.1
352	.846	.86	.6970	.91	.2984	1.3430	1.927	.0010	.0109	111.5
353	.794	.81	.6587	.86	.2999	1.2660	1.922	.0010	.0110	111.0
354	.730	.74	.6060	.79	.2964	1.1320	1.868	.0010	.0111	108.5
355	.697	.71	.5769	.76	.2927	1.0500	1.820	.0010	.0113	106.4
356	.646	.66	.5300	.70	.2850	.9516	1.795	.0010	.0112	106.3
357	.601	.61	.4873	.64	.2756	.8508	1.746	.0010	.0112	105.1
358	.555	.56	.4427	.58	.2646	.7360	1.663	.0010	.0114	102.2
359	.501	.51	.3896	.51	.2490	.6170	1.584	.0010	.0115	100.4
360	.390	.40	.2809	.37	.2094	.3730	1.328	.0010	.0118	91.7
361	.296	.30	.1928	.25	.1686	.2026	1.051	.0010	.0124	80.9
362 ¹	.974	.99	.7614	.99	.2640	1.9080	2.506	.0020	.0109	109.1
363	.853	.87	.7017	.92	.2978	1.7200	2.451	.0020	.0120	100.4
364	.807	.82	.6687	.88	.3000	1.6900	2.527	.0020	.0117	103.2
365	.764	.78	.6346	.83	.2991	1.5550	2.450	.0020	.0120	100.2
366	.701	.71	.5805	.76	.2932	1.3900	2.394	.0020	.0121	98.9
367	.646	.66	.5300	.70	.2850	1.1960	2.256	.0020	.0124	94.5
368	.590	.60	.4767	.63	.2733	1.0160	2.133	.0020	.0127	91.2
369	.549	.56	.4368	.57	.2630	.8904	2.038	.0020	.0128	88.9
370	.504	.51	.3925	.51	.2429	.7450	1.898	.0020	.0131	84.9
371	.406	.41	.2964	.39	.2157	.4657	1.571	.0020	.0130	75.6
372	.298	.30	.1947	.26	.1695	.2340	1.202	.0020	.0138	53.6

¹ These tests used in deriving formulae 27 and 29.

TABLE 3.—*Elements of experiments for clay tile—Continued.*

12-INCH TILE—Continued.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hy- draulic radius.	Dis- charge.	Ve- locity.	Slope.	Kutter coeffi- cient.	Chezy coeffi- cient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
	<i>Feet.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft. per sec.</i>	<i>Feet per sec.</i>			
373.....	0.887	0.90	0.7234	0.95	0.2938	2.2320	3.086	0.0030	0.0116	103.9
374.....	.853	.87	.7017	.92	.2978	2.1840	3.113	.0030	.0116	104.1
375.....	.809	.82	.6702	.88	.3000	2.0800	3.103	.0030	.0117	103.4
376.....	.773	.78	.6420	.84	.2995	1.9450	3.030	.0030	.0119	101.1
377.....	.724	.73	.6007	.79	.2957	1.7980	2.992	.0030	.0120	100.5
378.....	.693	.70	.5734	.75	.2923	1.6100	2.809	.0030	.0124	94.9
379.....	.646	.66	.5300	.70	.2850	1.4400	2.717	.0030	.0126	92.9
380.....	.603	.61	.4893	.64	.2761	1.2560	2.567	.0030	.0129	89.2
381.....	.547	.56	.4349	.57	.2624	1.0260	2.360	.0030	.0134	84.1
382.....	.500	.51	.3886	.51	.2487	.8440	2.173	.0030	.0138	79.6
383.....	.402	.41	.2925	.38	.2142	.5222	1.785	.0030	.0147	70.4
384.....	.303	.31	.1992	.26	.1718	.2737	1.374	.0030	.0158	60.5
385 ¹	.974	.99	.7614	.99	.2640	3.0380	3.990	.0050	.0109	109.8
386 ¹	.940	.95	.7504	.98	.2811	3.0030	4.002	.0050	.0113	106.8
387.....	.878	.89	.7179	.94	.2952	2.8400	3.956	.0050	.0117	103.0
388.....	.817	.83	.6763	.89	.2998	2.5440	3.762	.0050	.0124	97.2
389.....	.741	.75	.6154	.81	.2975	2.1300	3.461	.0050	.0131	89.7
390.....	.696	.71	.5760	.76	.2927	1.8400	3.195	.0050	.0138	83.5
391.....	.644	.65	.5282	.69	.2846	1.5650	2.963	.0050	.0144	78.6
392.....	.597	.61	.4835	.63	.2748	1.3550	2.803	.0050	.0147	75.6
393.....	.552	.56	.4398	.58	.2638	1.1660	2.651	.0050	.0150	73.0
394.....	.509	.52	.3975	.52	.2514	.9838	2.475	.0050	.0154	69.8
395.....	.409	.42	.2993	.39	.2169	.5981	1.998	.0050	.0165	60.7
396.....	.313	.32	.2083	.27	.1765	.3259	1.564	.0050	.0175	52.7
397.....	.723	.73	.5998	.79	.2956	2.9890	4.983	.0075	.0114	105.8
398.....	.638	.65	.5225	.69	.2834	2.5440	4.869	.0075	.0114	105.6
399.....	.584	.59	.4708	.62	.2719	2.1480	4.563	.0075	.0117	101.0
400.....	.563	.57	.4505	.59	.2667	2.0500	4.551	.0075	.0117	101.8
401.....	.512	.52	.4004	.53	.2523	1.7400	4.346	.0075	.0117	99.9
402.....	.388	.39	.2790	.37	.2086	1.0180	3.651	.0075	.0120	92.3
403.....	.302	.31	.1983	.26	.1714	.6250	3.153	.0075	.0119	87.9
404.....	.651	.66	.5347	.70	.2858	2.9400	5.498	.0100	.0117	102.8
405.....	.598	.61	.4844	.64	.2750	2.6170	5.403	.0100	.0116	103.0
406.....	.546	.55	.4339	.57	.2622	2.2980	5.297	.0100	.0114	103.5
407.....	.494	.50	.3827	.50	.2468	1.8400	4.809	.0100	.0119	96.8
408.....	.413	.42	.3031	.40	.2184	1.2960	4.276	.0100	.0121	91.5
409.....	.307	.31	.2028	.27	.1737	.6972	3.438	.0100	.0126	82.5
410.....	.496	.50	.3847	.50	.2474	2.0150	5.239	.0125	.0122	94.2
411.....	.419	.43	.3090	.41	.2207	1.5400	4.984	.0125	.0118	94.9
412.....	.321	.33	.2157	.28	.1801	.9694	4.495	.0125	.0114	94.7
413.....	.459	.47	.3482	.46	.2351	1.9600	5.630	.0150	.0120	94.8
414.....	.444	.45	.3335	.44	.2299	1.8575	5.570	.0150	.0119	94.9
415.....	.403	.41	.2935	.39	.2145	1.6150	5.525	.0150	.0116	97.0
416.....	.284	.29	.1820	.24	.1629	.8639	4.747	.0150	.0111	96.0

¹ These tests used in deriving formulæ 27 and 29.

TABLE 4.—*Elements of experiments for concrete tile.*

4-INCH TILE.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hy- draulic radius.	Dis- charge.	Ve- locity.	Slope.	Kutter coeffi- cient.	Chezy coeffi- cient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
	<i>Feet.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft. per sec.</i>	<i>Feet per sec.</i>			
417 ¹	0.328	1.00	0.0845	1.00	0.0820	0.0426	0.504	0.0005	0.0107	78.7
418	.282	.86	.0773	.92	.0993	.0386	.499	.0005	.0120	70.9
419	.247	.75	.0683	.81	.0990	.0335	.491	.0005	.0122	69.7
420	.206	.63	.0559	.66	.0930	.0196	.315	.0005	.0160	46.3
421	.167	.51	.0432	.51	.0829	.0120	.278	.0005	.0163	43.1
422	.118	.36	.0274	.32	.0649	2.0020	2.075	.0005	2.0352	2 13.1
423 ¹	.311	.95	.0828	.98	.0941	.0650	.785	.0010	.0110	80.9
424	.274	.84	.0754	.89	.0997	.0550	.730	.0010	.0120	73.1
425	.239	.73	.0660	.78	.0982	.0450	.682	.0010	.0124	68.8
426	.210	.64	.0571	.68	.0938	.0375	.656	.0010	.0124	67.8
427	.163	.50	.0419	.50	.0817	.0218	.519	.0010	.0134	57.4
428	.118	.36	.0274	.32	.0649	.0083	.301	.0010	.0172	37.4
429 ¹	.323	.99	.0842	.99	.0890	.0832	.988	.0020	.0116	74.1
430	.271	.83	.0747	.88	.0998	.0800	1.071	.0020	.0117	75.8
431	.243	.74	.0671	.79	.0986	.0650	.968	.0020	.0125	68.9
432	.215	.66	.0587	.70	.0948	.0544	.927	.0020	.0126	67.3
433	.162	.49	.0416	.49	.0814	.0280	.673	.0020	.0144	52.8
434	.124	.38	.0293	.35	.0674	.0127	.434	.0020	.0175	37.4
435 ¹	.323	.99	.0842	.99	.0886	.1014	1.204	.0030	.0117	73.8
436	.295	.90	.0801	.95	.0978	.1041	1.300	.0030	.0117	75.9
437	.271	.83	.0747	.88	.0998	.0969	1.298	.0030	.0119	75.0
438	.243	.74	.0671	.79	.0986	.0848	1.263	.0030	.0120	73.4
439	.211	.64	.0575	.68	.0940	.0591	1.028	.0030	.0135	61.2
440	.160	.49	.0409	.48	.0807	.0298	.727	.0030	.0157	46.7
441	.118	.36	.0274	.32	.0649	.0130	.475	.0030	.0185	34.1
442 ¹	.315	.96	.0834	.99	.0928	.1415	1.697	.0050	.0113	78.8
443	.276	.84	.0759	.90	.0996	.1235	1.627	.0050	.0121	72.9
444	.243	.74	.0671	.79	.0986	.0996	1.484	.0050	.0129	66.8
445	.212	.65	.0578	.68	.0943	.0788	1.364	.0050	.0133	62.8
446	.170	.52	.0442	.52	.0838	.0478	1.081	.0050	.0146	52.8
447	.121	.37	.0283	.34	.0661	.0200	.706	.0050	.0171	38.9
448 ¹	.305	.93	.0819	.97	.0959	.1775	2.168	.0075	.0112	80.8
449	.290	.88	.0790	.94	.0985	.1686	2.133	.0075	.0116	78.5
450	.269	.82	.0742	.88	.0998	.1459	1.968	.0075	.0123	71.9
451	.252	.77	.0697	.83	.0994	.1299	1.866	.0075	.0127	68.3
452	.222	.68	.0609	.72	.0961	.0956	1.571	.0075	.0141	58.5
453	.191	.58	.0511	.61	.0897	.0696	1.362	.0075	.0150	52.5
454	.173	.53	.0452	.54	.0847	.0594	1.314	.0075	.0149	52.1
455	.296	.90	.0803	.95	.0976	.1931	2.406	.0100	.0117	77.0
456	.291	.89	.0792	.94	.0984	.1905	2.404	.0100	.0118	76.6
457	.278	.85	.0764	.90	.0995	.1686	2.208	.0100	.0125	70.0
458	.249	.76	.0688	.81	.0992	.1382	2.008	.0100	.0134	63.8
459	.209	.64	.0568	.67	.0936	.1046	1.840	.0100	.0138	60.1
460	.165	.50	.0426	.50	.0823	.0622	1.461	.0100	.0151	50.9
461 ¹	.301	.92	.0812	.96	.0967	.2250	2.771	.0125	.0114	79.7
462	.287	.88	.0784	.93	.0988	.2124	2.709	.0125	.0117	77.1
463	.242	.74	.0668	.79	.0985	.1656	2.478	.0125	.0124	70.6
464	.204	.62	.0552	.65	.0926	.1377	2.492	.0125	.0120	73.3
465	.196	.60	.0396	.47	.0793	.0760	1.918	.0125	.0132	60.9
466	.133	.41	.0322	.38	.0710	.0416	1.293	.0125	.0163	43.4
467 ¹	.314	.96	.0833	.99	.0931	.2544	3.056	.0150	.0111	81.8
468	.302	.92	.0814	.96	.0965	.2456	3.018	.0150	.0114	79.3
469	.271	.84	.0754	.89	.0997	.2235	2.965	.0150	.0118	76.7
470	.255	.78	.0705	.83	.0996	.1892	2.684	.0150	.0126	69.5
471	.224	.68	.0615	.73	.0964	.1506	2.449	.0150	.0128	66.3
472	.159	.49	.0406	.48	.0804	.0848	2.088	.0150	.0133	60.1
473	.123	.38	.0290	.34	.0669	.0438	1.511	.0150	.0150	47.7

¹ These tests used in deriving formulæ 26 and 28.² Evidently an incorrect hook-page reading.

TABLE 4.—*Elements of experiments for concrete tile—Continued.*

5-INCH TILE.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hy- draulic radins.	Dis- charge.	Ve- locity.	Slope.	Kutter coeff- icient.	Chezy coeff- icient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
	<i>Feet.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft. per sec.</i>	<i>Feet per sec.</i>			
474 ¹	0.396	0.96	0.1319	0.99	0.1169	0.0844	0.640	0.0005	0.0110	83.7
475	.308	.75	.1071	.80	.1243	.0671	.627	.0005	.0116	79.5
476	.221	.54	.0729	.55	.1076	.0346	.475	.0005	.0131	64.7
477 ¹	.405	.98	.1332	.99	.1125	.1305	.980	.0010	.0103	92.4
478	.293	.71	.1016	.76	.1227	.0969	.954	.0010	.0111	86.1
479	.206	.50	.0667	.50	.1031	.0448	.671	.0010	.0130	66.1
480	.134	.32	.0377	.28	.0752	.0196	.521	.0010	.0130	60.1
481 ¹	.393	.95	.1314	.98	.1179	.1840	1.400	.0020	.0106	91.2
482	.317	.77	.1102	.82	.1251	.1608	1.459	.0020	.0107	92.2
483	.223	.54	.0738	.55	.1082	.0848	1.150	.0020	.0117	78.2
484	.171	.41	.0524	.39	.0907	.0466	.890	.0020	.0127	66.1
485	.126	.31	.0346	.26	.0715	.0256	.740	.0020	.0126	61.9
486 ¹	.404	.98	.1331	.99	.1131	.2303	1.730	.0030	.0104	93.9
487	.310	.75	.1073	.81	.1246	.1853	1.719	.0030	.0110	88.9
488	.209	.51	.0680	.51	.1040	.0828	1.218	.0030	.0127	69.0
489	.159	.38	.0475	.36	.0859	.0404	.851	.0030	.0146	53.0
490	.119	.29	.0319	.24	.0683	.0150	.470	.0030	.0191	32.9
491 ¹	.398	.96	.1323	.99	.1160	.3052	2.307	.0050	.0103	95.8
492	.278	.67	.0959	.72	.1207	.2020	2.107	.0050	.0113	85.8
493	.193	.47	.0613	.46	.0987	.1023	1.668	.0050	.0119	75.1
494	.159	.38	.0475	.36	.0859	.0622	1.310	.0050	.0130	63.2
495	.114	.27	.0301	.23	.0659	.0283	.940	.0050	.0139	52.2
496 ¹	.393	.95	.1314	.98	.1179	.3563	2.711	.0075	.0107	91.2
497	.316	.77	.1099	.82	.1250	.2814	2.560	.0075	.0116	83.6
498	.196	.47	.0626	.47	.0997	.1349	2.154	.0075	.0115	78.8
499	.146	.35	.0423	.32	.0805	.0748	1.767	.0075	.0117	71.9
500	.126	.31	.0346	.26	.0715	.0439	1.270	.0075	.0138	54.8
501 ¹	.404	.98	.1331	.99	.1131	.4282	3.218	.0100	.0103	95.7
502	.298	.72	.1034	.77	.1233	.3105	3.003	.0100	.0114	85.5
503	.224	.54	.0742	.56	.1085	.2318	3.124	.0100	.0102	94.9
504	.195	.47	.0614	.46	.0987	.1644	2.680	.0100	.0109	85.3
505	.135	.33	.0380	.28	.0757	.0736	1.935	.0100	.0117	70.3
506 ¹	.396	.96	.1319	.99	.1169	.4669	3.538	.0125	.0106	92.6
507	.312	.76	.1085	.81	.1247	.3660	3.374	.0125	.0114	85.4
508	.231	.56	.0771	.58	.1104	.2688	3.489	.0125	.0104	93.9
509	.188	.46	.0593	.44	.0970	.1892	3.189	.0125	.0102	91.6
510	.129	.31	.0357	.27	.0729	.0920	2.574	.0125	.0101	85.3
511 ¹	.401	.97	.1327	.99	.1147	.5162	3.891	.0150	.0104	93.8
512	.323	.78	.1123	.84	.1254	.4565	4.065	.0150	.0107	93.8
513	.261	.63	.0892	.67	.1174	.3150	3.533	.0150	.0114	84.2
514	.176	.43	.0544	.41	.0926	.1548	2.846	.0150	.0116	76.4

6-INCH TILE.

515 ¹	0.492	0.99	0.1937	0.99	0.1325	0.1366	0.705	0.0005	0.0111	86.6
516	.391	.79	.1637	.84	.1510	.0888	.542	.0005	.0145	62.4
517	.282	.57	.1136	.59	.1340	.0463	.408	.0005	.0164	49.8
518	.225	.45	.0853	.44	.1163	.0343	.401	.0005	.0154	52.6
519	.173	.35	.0601	.31	.0958	.0206	.343	.0005	.0152	49.6
520 ¹	.484	.97	.1926	.99	.1375	.2187	1.136	.0010	.0104	96.8
521	.384	.77	.1608	.83	.1508	.1795	1.116	.0010	.0110	90.9
522	.298	.60	.1214	.63	.1379	.1070	.881	.0010	.0126	75.0
523	.222	.45	.0838	.43	.1152	.0535	.638	.0010	.0142	59.5
524	.176	.35	.0615	.32	.0971	.0295	.480	.0010	.0159	48.7
525 ¹	.481	.97	.1921	.99	.1390	.3026	1.575	.0020	.0107	94.5
526	.371	.75	.1553	.80	.1498	.2378	1.531	.0020	.0115	88.5
527	.293	.59	.1190	.61	.1368	.1578	1.326	.0020	.0121	80.2
528	.216	.43	.0809	.42	.1130	.0880	1.088	.0020	.0124	72.4
529	.170	.34	.0587	.30	.0944	.0459	.783	.0020	.0142	57.0

¹ These tests used in deriving formulæ 26 and 28.

TABLE 4.—*Elements of experiments for concrete tile—Continued.*

6-INCH TILE—Continued.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow	d D	Area of flow.	a A	Hy- draulic radius.	Dis- charge.	Ve- locity.	Slope.	Kutter coeff- icient.	Chezy coeff- icient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
	<i>Feet.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft. per sec.</i>	<i>Feet per sec.</i>			
530 ¹	0.489	0.98	0.1933	0.99	0.1346	0.3831	1.983	0.0030	0.0103	98.7
531.....	.383	.77	.1604	.83	.1507	.3177	1.981	.0030	.0111	93.1
532.....	.273	.55	.1091	.56	.1315	.1795	1.644	.0030	.0117	82.8
533.....	.222	.45	.0839	.43	.1152	.1190	1.419	.0030	.0121	76.3
534.....	.164	.33	.0558	.29	.0919	.0550	.985	.0030	.0137	59.4
535 ¹	.480	.97	.1919	.99	.1394	.4335	2.259	.0050	.0116	85.6
536.....	.385	.77	.1612	.83	.1508	.3915	2.428	.0050	.0115	88.4
537.....	.270	.54	.1077	.56	.1307	.2082	1.934	.0050	.0126	75.7
538.....	.210	.42	.0779	.40	.1108	.1250	1.604	.0050	.0129	68.2
539.....	.151	.30	.0498	.26	.0858	.0615	1.234	.0050	.0135	59.6
540 ¹	.480	.97	.1919	.99	.1394	.5874	3.061	.0075	.0108	94.7
541.....	.384	.77	.1608	.83	.1508	.4691	2.917	.0075	.0117	86.8
542.....	.272	.55	.1087	.56	.1313	.2680	2.466	.0075	.0121	78.6
543.....	.212	.43	.0789	.41	.1115	.1602	2.030	.0075	.0126	70.2
544.....	.142	.29	.0457	.24	.0816	.0633	1.383	.0075	.0139	55.9
545 ¹	.473	.95	.1905	.98	.1421	.6238	3.274	.0100	.0116	86.9
546.....	.365	.73	.1527	.79	.1491	.4807	3.148	.0100	.0123	81.5
547.....	.278	.56	.1116	.58	.1329	.3186	2.854	.0100	.0123	78.3
548.....	.212	.43	.0789	.41	.1115	.1991	2.523	.0100	.0122	75.5
549.....	.144	.29	.0466	.24	.0825	.0904	1.939	.0100	.0123	67.5
550.....	.440	.89	.1816	.94	.1492	.6874	3.785	.0125	.0116	87.7
551.....	.431	.87	.1787	.92	.1500	.6818	3.815	.0125	.0114	88.1
552.....	.350	.70	.1406	.75	.1474	.5306	3.635	.0125	.0118	84.7
553.....	.264	.53	.1047	.54	.1289	.3402	3.249	.0125	.0119	80.9
554.....	.202	.41	.0740	.38	.1077	.2096	2.832	.0125	.0119	77.2
555.....	.132	.27	.0413	.21	.0767	.0706	1.709	.0125	.0139	55.2
556.....	.435	.88	.1800	.93	.1497	.7705	4.280	.0150	.0113	90.3
557.....	.352	.71	.1469	.76	.1477	.5941	4.043	.0150	.0117	85.9
558.....	.258	.52	.1017	.52	.1271	.3630	3.569	.0150	.0118	81.7
559.....	.193	.39	.0696	.36	.1041	.2325	3.339	.0150	.0111	84.5
560.....	.123	.25	.0374	.19	.0723	.0936	2.504	.0150	.0110	76.1

8-INCH TILE

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow	d D	Area of flow.	a A	Hy- draulic radius.	Dis- charge.	Ve- locity.	Slope.	Kutter coeff- icient.	Chezy coeff- icient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
561 ¹	0.645	0.98	0.3389	0.99	0.1803	0.3096	0.914	0.0005	0.0109	96.2
562 ¹	.642	.98	.3383	.99	.1818	.3096	.915	.0005	.0109	96.0
563.....	.547	.83	.3024	.89	.2002	.2873	.950	.0005	.0113	94.9
564.....	.479	.73	.2654	.78	.1970	.2187	.824	.0005	.0124	83.0
565.....	.426	.65	.2331	.68	.1893	.1957	.840	.0005	.0120	86.3
566.....	.319	.48	.1635	.48	.1612	.1105	.676	.0005	.0128	75.3
567.....	.258	.39	.1237	.36	.1389	.0720	.582	.0005	.0134	69.8
568.....	.180	.27	.0755	.22	.1042	.0323	.428	.0005	.0137	59.3
569 ¹	.654	.99	.3402	.99	.1720	.4440	1.305	.0010	.0107	99.5
570 ¹	.625	.93	.3341	.98	.1888	.4261	1.276	.0010	.0116	92.9
571.....	.554	.84	.3058	.90	.2000	.4104	1.342	.0010	.0115	94.9
572.....	.481	.73	.2666	.78	.1972	.3278	1.227	.0010	.0121	87.6
573.....	.428	.65	.2343	.69	.1897	.2839	1.212	.0010	.0120	88.0
574.....	.311	.47	.1583	.47	.1585	.1638	1.036	.0010	.0121	82.3
575.....	.253	.38	.1205	.35	.1368	.1130	.937	.0010	.0120	80.1
576.....	.177	.27	.0737	.22	.1027	.0463	.628	.0010	.0136	62.0
577 ¹	.648	.98	.3394	.99	.1782	.6373	1.882	.0020	.0109	99.7
578 ¹	.640	.97	.3379	.99	.1828	.6496	1.923	.0020	.0108	100.5
579.....	.565	.86	.3110	.91	.1994	.6035	1.940	.0020	.0113	97.2
580.....	.466	.75	.2752	.84	.1988	.5090	1.850	.0020	.0117	92.4
581.....	.448	.68	.2467	.72	.1933	.4387	1.778	.0020	.0119	90.7
582.....	.335	.51	.1741	.51	.1664	.2616	1.503	.0020	.0124	82.4
583.....	.263	.40	.1270	.37	.1409	.1602	1.260	.0020	.0128	75.1
584.....	.180	.27	.0755	.22	.1042	.0664	.879	.0020	.0139	60.9

¹ These tests used in deriving formulæ 26 and 28.

TABLE 4.—*Elements of experiments for concrete tile—Continued.*

8-INCH TILE—Continued.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hydraulic radius.	Discharge.	Velocity.	Slope.	Kutter coefficient.	Chezy coefficient.
	(d)		(a)		(R)	(Q)	V	(s)	(n)	(C)
	Feet.		Sq. ft.		Feet.	Cu. ft. per sec.	Feet per sec.			
585 ¹	0.643	0.98	0.3385	0.99	0.1813	0.7870	02.325	0.0030	0.0109	99.7
586 ¹	.623	.95	.3334	.98	.1894	.7750	2.324	.0030	.0112	97.5
587	.553	.84	.3053	.90	.2001	.7240	2.371	.0030	.0114	96.8
588	.489	.74	.2712	.80	.1981	.6224	2.295	.0030	.0116	94.1
589	.445	.68	.2449	.72	.1928	.5440	2.221	.0030	.0118	92.4
590	.341	.52	.1780	.52	.1682	.3354	1.884	.0030	.0123	83.9
591	.262	.40	.1263	.37	.1405	.1886	1.492	.0030	.0131	72.7
592	.182	.28	.0767	.23	.1051	.0824	1.075	.0030	.0140	60.5
593 ¹	.647	.98	.3392	.99	.1789	1.0105	2.979	.0050	.0109	99.6
594 ¹	.628	.95	.3349	.98	.1877	1.0164	3.035	.0050	.0110	99.1
595	.623	.95	.3334	.98	.1894	.9930	2.978	.0050	.0113	96.8
596	.566	.86	.3115	.92	.1993	.9108	2.924	.0050	.0117	92.7
597	.512	.78	.2841	.83	.1999	.8028	2.825	.0050	.0121	89.4
598	.443	.67	.2437	.72	.1924	.6440	2.642	.0050	.0124	85.2
599	.318	.48	.1629	.48	.1609	.3610	2.216	.0050	.0128	78.1
600	.270	.41	.1315	.39	.1436	.2608	1.983	.0050	.0130	74.0
601	.189	.29	.0808	.24	.1085	.1140	1.411	.0050	.0141	60.6
602 ¹	.647	.98	.3392	.99	.1790	1.1900	3.508	.0075	.0112	95.8
603 ¹	.633	.96	.3362	.99	.1860	1.2280	3.652	.0075	.0112	97.0
604	.546	.83	.3019	.89	.2003	1.0880	3.603	.0075	.0117	93.0
605	.495	.75	.2746	.81	.1988	.9658	3.517	.0075	.0118	91.1
606	.442	.67	.2431	.71	.1922	.8204	3.375	.0075	.0120	88.9
607	.335	.51	.1741	.51	.1664	.5042	2.896	.0075	.0122	82.0
608	.260	.39	.1250	.37	.1397	.3096	2.476	.0075	.0125	76.5
609	.170	.26	.0697	.21	.0992	.1215	1.743	.0075	.0132	63.9
610 ¹	.645	.98	.3389	.99	.1803	1.3580	4.007	.0100	.0114	94.4
611 ¹	.642	.98	.3383	.99	.1818	1.3630	4.030	.0100	.0114	94.5
612	.559	.85	.3082	.91	.1998	1.2680	4.114	.0100	.0117	92.1
613	.464	.71	.2565	.75	.1954	1.0470	4.082	.0100	.0117	92.3
614	.415	.63	.2261	.66	.1870	.8788	3.886	.0100	.0118	89.9
615	.309	.47	.1570	.46	.1579	.5318	3.388	.0100	.0119	85.3
616	.225	.34	.1028	.30	.1250	.2899	2.820	.0100	.0120	79.8
617	.153	.23	.0601	.18	.0906	.1283	2.136	.0100	.0120	71.0
618 ¹	.642	.98	.3383	.99	.1818	1.5120	4.470	.0125	.0115	93.8
619 ¹	.600	.91	.3257	.96	.1950	1.4880	4.569	.0125	.0118	92.5
620	.593	.90	.3229	.95	.1962	1.4700	4.553	.0125	.0118	91.9
621	.553	.84	.3054	.90	.2001	1.4080	4.611	.0125	.0118	92.2
622	.487	.74	.2701	.79	.1979	1.2040	4.459	.0125	.0120	89.6
623	.426	.65	.2331	.68	.1893	.9928	4.260	.0125	.0121	87.6
624	.324	.49	.1668	.49	.1629	.6224	3.731	.0125	.0122	82.7
625	.244	.37	.1148	.34	.1332	.3620	3.153	.0125	.0123	77.3
626	.163	.25	.0656	.19	.0957	.1602	2.441	.0125	.0122	70.6
627 ¹	.634	.96	.3365	.99	.1856	1.6450	4.889	.0150	.0116	92.7
628 ¹	.616	.94	.3313	.97	.1915	1.6425	4.959	.0150	.0115	92.5
629	.545	.83	.3015	.89	.2003	1.5060	4.996	.0150	.0118	91.1
630	.482	.73	.2671	.78	.1974	1.2900	4.829	.0150	.0120	88.7
631	.414	.63	.2255	.66	.1868	1.0140	4.500	.0150	.0122	85.0
632	.323	.49	.1662	.49	.1626	.6524	3.926	.0150	.0126	79.5
633	.245	.37	.1155	.34	.1336	.3925	3.399	.0150	.0123	75.9
634	.165	.25	.0668	.19	.0967	.1879	2.813	.0150	.0120	73.9

10-INCH TILE.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hydraulic radius.	Discharge.	Velocity.	Slope.	Kutter coefficient.	Chezy coefficient.
	(d)		(a)		(R)	(Q)	V	(s)	(n)	(C)
	Feet.		Sq. ft.		Feet.	Cu. ft. per sec.	Feet per sec.			
635 ¹	0.818	0.99	0.5366	0.99	0.2213	0.4818	0.898	0.0005	0.0125	85.4
636 ¹	.783	.95	.5265	.98	.2379	.5150	.978	.0005	.0122	89.7
637	.739	.89	.5068	.94	.2475	.5114	1.009	.0005	.0122	90.7
638	.706	.85	.4887	.91	.2508	.4910	1.005	.0005	.0123	89.7
639	.666	.81	.4638	.86	.2518	.4429	.955	.0005	.0128	86.1
640	.616	.75	.4293	.80	.2491	.4324	1.007	.0006	.0122	90.3
641	.579	.70	.4018	.75	.2451	.4188	1.042	.0005	.0118	94.1
642	.551	.67	.3803	.71	.2408	.3666	.962	.0005	.0124	87.7
643	.474	.57	.3186	.59	.2243	.2780	.873	.0005	.0129	82.4
644	.416	.50	.2708	.50	.2076	.2408	.889	.0005	.0122	87.3
645	.323	.39	.1944	.36	.1741	.1470	.756	.0005	.0123	81.1
646	.241	.29	.1302	.24	.1380	.0832	.639	.0005	.0122	77.0

¹ These tests used in deriving formulæ 26 and 28.

TABLE 4.—Elements of experiments for concrete tile—Continued.

10-INCH TILE—Continued.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hydraulic radius.	Discharge.	Velocity.	Slope.	Kutter coefficient.	Chezy coefficient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
	<i>Feet.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft. per sec.</i>	<i>Feet per sec.</i>			
617 ¹	0.814	0.98	0.5357	0.99	0.2241	0.7240	1.351	0.0010	0.0121	90.3
618 ¹	.811	.98	.5351	.99	.2262	.7510	1.403	.0010	.0119	93.3
619 ¹	.789	.95	.5286	.98	.2360	.7780	1.472	.0010	.0117	95.8
650	.739	.89	.5068	.94	.2475	.7615	1.503	.0010	.0119	95.5
651	.710	.86	.4910	.91	.2505	.7360	1.499	.0010	.0120	94.8
652	.670	.81	.4664	.87	.2519	.6930	1.486	.0010	.0121	93.6
653	.617	.75	.4300	.80	.2493	.6278	1.460	.0010	.0121	92.5
654	.593	.72	.4124	.77	.2466	.5954	1.444	.0010	.0122	91.9
655	.557	.67	.3850	.72	.2419	.5354	1.391	.0010	.0124	89.4
656	.486	.59	.3283	.61	.2273	.4462	1.359	.0010	.0122	90.1
657	.423	.51	.2766	.51	.2097	.3650	1.320	.0010	.0119	91.1
658	.322	.39	.1936	.36	.1736	.1998	1.032	.0010	.0128	78.3
659	.238	.29	.1280	.24	.1366	.1110	.868	.0010	.0126	74.3
660 ¹	.813	.98	.5355	.99	.2248	1.1160	2.084	.0020	.0114	98.3
661 ¹	.798	.97	.5316	.99	.2326	1.1020	2.073	.0020	.0117	96.1
662 ¹	.797	.96	.5313	.99	.2330	1.1360	2.138	.0020	.0115	99.1
663	.738	.89	.5063	.94	.2476	1.0960	2.165	.0020	.0118	97.3
664	.708	.86	.4899	.91	.2506	1.0600	2.164	.0020	.0119	96.7
665	.667	.81	.4644	.86	.2518	1.0105	2.176	.0020	.0119	97.0
666	.621	.75	.4329	.81	.2497	.9448	2.183	.0020	.0118	97.7
667	.594	.72	.4132	.77	.2467	.8639	2.091	.0020	.0121	94.1
668	.561	.68	.3881	.72	.2425	.7996	2.060	.0020	.0121	93.6
669	.483	.58	.3259	.61	.2265	.6251	1.918	.0020	.0123	90.2
670	.439	.53	.2898	.54	.2145	.5186	1.790	.0020	.0125	86.4
671	.429	.52	.2815	.52	.2115	.4982	1.770	.0020	.0125	86.0
672	.343	.41	.2106	.39	.1819	.3250	1.543	.0020	.0127	80.9
673	.248	.30	.1355	.25	.1413	.1437	1.060	.0020	.0145	63.1
674 ¹	.813	.98	.5356	.99	.2248	1.3400	2.502	.0030	.0117	96.3
675 ¹	.810	.98	.5349	.99	.2267	1.3380	2.502	.0030	.0117	95.9
676 ¹	.790	.95	.5290	.98	.2356	1.3800	2.609	.0030	.0116	98.1
677	.740	.89	.5073	.94	.2473	1.3450	2.651	.0030	.0118	97.3
678	.715	.86	.4939	.92	.2501	1.3280	2.689	.0030	.0117	98.2
679	.663	.80	.4619	.86	.2517	1.2360	2.676	.0030	.0118	97.4
680	.636	.77	.4435	.83	.2508	1.1800	2.661	.0030	.0119	97.0
681	.598	.72	.4161	.77	.2472	1.0760	2.584	.0030	.0120	95.0
682	.554	.67	.3827	.71	.2413	.9586	2.505	.0030	.0122	93.1
683	.498	.60	.3381	.63	.2300	.8092	2.393	.0030	.0123	91.1
684	.436	.53	.2873	.53	.2136	.6332	2.205	.0030	.0125	87.1
685	.339	.41	.2074	.39	.1804	.3791	1.828	.0030	.0130	78.6
686	.243	.29	.1317	.25	.1390	.1853	1.407	.0030	.0136	68.9
687 ¹	.805	.97	.5336	.99	.2294	1.7650	3.308	.0050	.0116	97.7
688 ¹	.804	.97	.5333	.99	.2299	1.7350	3.253	.0050	.0118	96.0
689	.789	.95	.5287	.98	.2360	1.7350	3.282	.0050	.0119	95.6
690	.741	.90	.5078	.95	.2471	1.7300	3.407	.0050	.0119	96.9
691	.704	.85	.4875	.91	.2509	1.6825	3.451	.0050	.0119	97.5
692	.678	.82	.4716	.88	.2518	1.6250	3.446	.0050	.0119	97.2
693	.623	.75	.4343	.81	.2498	1.4800	3.408	.0050	.0120	96.4
694	.586	.71	.4072	.76	.2458	1.3450	3.303	.0050	.0121	94.2
695	.562	.68	.3889	.72	.2427	1.2480	3.209	.0050	.0123	92.1
696	.492	.60	.3332	.62	.2286	.9930	2.980	.0050	.0126	88.1
697	.420	.51	.2741	.51	.2088	.7345	2.680	.0050	.0129	82.9
698	.338	.41	.2066	.38	.1800	.4934	2.388	.0050	.0129	79.6
699	.231	.28	.1227	.23	.1332	.2222	1.810	.0050	.0133	70.2
700 ¹	.793	.96	.5300	.99	.2346	1.7600	3.321	.0050	.0117	97.0
701 ¹	.785	.95	.5272	.98	.2373	1.7400	3.300	.0050	.0119	95.8
702 ¹	.772	.93	.5222	.97	.2411	1.7175	3.289	.0050	.0120	94.7
703	.729	.88	.5016	.93	.2488	1.7100	3.409	.0050	.0119	96.7
704	.686	.83	.4766	.89	.2516	1.6250	3.410	.0050	.0120	96.1
705	.621	.75	.4329	.81	.2497	1.4840	3.428	.0050	.0119	97.1
706	.593	.72	.4124	.77	.2466	1.3400	3.249	.0050	.0123	92.5
707	.566	.68	.3919	.73	.2434	1.2460	3.179	.0050	.0124	91.1
708	.499	.60	.3389	.63	.2302	.9949	2.936	.0050	.0128	86.5
709	.421	.51	.2749	.51	.2091	.7315	2.661	.0050	.0130	82.0
710	.341	.41	.2090	.39	.1812	.4887	2.338	.0050	.0132	77.7
711	.232	.28	.1235	.23	.1337	.2236	1.811	.0050	.0134	70.3

¹ These tests used in deriving formulæ 26 and 28.

TABLE 4.—*Elements of experiments for concrete tile—Continued.*

10-INCH TILE—Continued.

1	1	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hydraulic radius.	Discharge.	Velocity.	Slope.	Kutter coefficient.	Chezy coefficient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
	<i>Feet.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft. per sec.</i>	<i>Feet per sec.</i>			
712 ¹	0.806	0.97	0.5338	0.99	0.2288	2.1150	3.962	0.0075	0.0118	95.7
713 ¹	.800	.97	.5322	.99	.2317	2.0900	3.927	.0075	.0120	94.2
714 ¹	.779	.94	.5250	.98	.2392	2.0850	3.972	.0075	.0121	93.8
715	.726	.88	.5000	.93	.2491	2.0560	4.112	.0075	.0121	95.2
716	.718	.87	.4956	.92	.2498	2.0440	4.125	.0075	.0120	95.3
717	.659	.80	.4592	.85	.2616	1.8870	4.110	.0075	.0121	94.6
718	.627	.76	.4371	.81	.2501	1.7700	4.050	.0075	.0122	93.5
719	.570	.69	.3950	.74	.2440	1.5120	3.828	.0075	.0126	89.5
720	.541	.65	.3724	.69	.2389	1.3800	3.706	.0075	.0128	87.5
721	.487	.59	.3291	.61	.2275	1.1560	3.512	.0075	.0129	85.0
722	.408	.49	.2642	.49	.2050	.8044	3.045	.0075	.0136	77.7
723	.323	.39	.1944	.36	.1740	.5306	2.729	.0075	.0133	75.5
724	.224	.27	.1176	.22	.1299	.2600	2.211	.0075	.0131	70.9
725 ¹	.792	.96	.5297	.99	.2349	2.4060	4.542	.0100	.0121	93.7
726 ¹	.791	.96	.5294	.99	.2353	2.4210	4.574	.0100	.0120	94.3
727	.681	.82	.4735	.88	.2517	2.2080	4.663	.0100	.0123	92.9
728	.624	.75	.4350	.81	.2499	2.0560	4.727	.0100	.0122	94.6
729	.618	.75	.4307	.80	.2493	2.0050	4.655	.0100	.0123	93.2
730	.595	.72	.4139	.77	.2468	1.8840	4.552	.0100	.0124	91.6
731	.553	.67	.3819	.71	.2411	1.6450	4.308	.0100	.0128	87.7
732	.489	.59	.3308	.62	.2280	1.3750	4.157	.0100	.0127	87.1
733	.405	.49	.2616	.49	.2040	.9930	3.795	.0100	.0128	84.0
734	.327	.40	.1976	.37	.1756	.6238	3.156	.0100	.0134	75.3
735	.207	.25	.1052	.20	.1214	.2318	2.203	.0100	.0141	63.2
736 ¹	.810	.98	.5349	.99	.2267	2.7040	5.055	.0125	.0119	95.0
737 ¹	.809	.98	.5346	.99	.2273	2.7220	5.092	.0125	.0118	95.5
738 ¹	.805	.97	.5336	.99	.2294	2.6890	5.040	.0125	.0120	94.1
739	.742	.90	.5083	.95	.2470	2.6800	5.272	.0125	.0121	94.9
740	.701	.85	.4857	.90	.2511	2.5920	5.336	.0125	.0121	95.2
741	.700	.85	.4852	.90	.2511	2.5920	5.343	.0125	.0121	95.4
742	.664	.80	.4625	.86	.2517	2.4660	5.332	.0125	.0121	95.1
743	.611	.74	.4257	.79	.2486	2.2410	5.265	.0125	.0122	94.5
744	.569	.69	.3942	.73	.2438	2.0000	5.073	.0125	.0124	91.9
745	.543	.66	.3740	.70	.2393	1.8840	5.037	.0125	.0123	92.1
746	.463	.56	.3096	.58	.2213	1.4620	4.725	.0125	.0123	89.8
747	.412	.50	.2674	.50	.2063	1.2360	4.622	.0125	.0120	91.0
748	.314	.38	.1872	.35	.1704	.7000	3.739	.0125	.0126	81.0
749	.213	.26	.1096	.20	.1244	.3260	2.983	.0125	.0124	75.6
750 ¹	.781	.94	.5257	.98	.2386	2.8840	5.486	.0150	.0123	91.7
751	.624	.75	.4350	.81	.2499	2.4540	5.641	.0150	.0124	92.1
752	.421	.51	.2749	.51	.2091	1.3820	5.030	.0150	.0122	89.8

12-INCH TILE.

1	1	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hydraulic radius.	Discharge.	Velocity.	Slope.	Kutter coefficient.	Chezy coefficient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
	<i>Feet.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft. per sec.</i>	<i>Feet per sec.</i>			
753 ¹	0.985	0.99	0.7712	0.99	0.2587	0.9125	1.183	0.0005	0.0110	104.1
754	.943	.95	.7581	.98	.2836	.8938	1.179	.0005	.0117	99.0
755	.889	.90	.7299	.95	.2960	.8672	1.188	.0005	.0119	97.6
756	.845	.85	.7011	.91	.3006	.8492	1.211	.0005	.0118	98.8
757	.782	.79	.6532	.85	.3014	.7540	1.154	.0005	.0123	94.1
758	.756	.76	.6317	.82	.3001	.6986	1.106	.0005	.0127	90.3
759	.691	.70	.5745	.74	.2933	.6496	1.131	.0005	.0123	93.4
760	.643	.65	.5298	.69	.2854	.6062	1.144	.0005	.0120	95.8
761	.580	.59	.4692	.61	.2717	.4982	1.062	.0005	.0124	91.1
762	.534	.54	.4240	.55	.2594	.4485	1.058	.0005	.0120	92.9
763	.511	.52	.4012	.52	.2526	.4083	1.018	.0005	.0123	90.6
764	.364	.37	.2570	.33	.1991	.2152	.837	.0005	.0123	83.9
765	.275	.28	.1747	.23	.1588	.1120	.641	.0005	.0132	72.0

¹ These tests used in deriving formulæ 26 and 28.

TABLE 4.—*Elements of experiments for concrete tile—Continued.*

12-INCH TILE.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	d D	Area of flow.	$\frac{a}{A}$	Hydraulic radius.	Discharge.	Velocity.	Slope.	Kutter coefficient.	Chezy coefficient.
	(d)		(a)		(E)	(Q)	(V)	(s)	(n)	(C)
	<i>Feet.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft. per sec.</i>	<i>Feet per sec.</i>			
766 ¹	0.953	0.96	0.7623	9.99	0.2801	1.3180	1.729	0.0010	0.0115	103.3
767	.950	.96	.7610	.99	.2812	1.2980	1.706	.0010	.0116	101.7
768	.880	.89	.7244	.94	.2974	1.2400	1.720	.0010	.0119	99.8
769	.831	.84	.6910	.90	.3013	1.1900	1.722	.0010	.0120	99.2
770	.774	.78	.6467	.84	.3012	1.0920	1.689	.0010	.0122	97.3
771	.741	.75	.6189	.80	.2989	1.0164	1.642	.0100	.0124	95.0
772	.680	.69	.5645	.73	.2919	.9312	1.650	.0010	.0121	96.6
773	.631	.64	.5184	.67	.2828	.8492	1.638	.0010	.0120	97.4
774	.581	.59	.4701	.61	.2720	.7255	1.543	.0010	.0123	93.6
775	.531	.54	.4211	.55	.2585	.6278	1.491	.0010	.0122	92.7
776	.471	.47	.3616	.47	.2397	.5114	1.414	.0010	.0122	91.4
777	.360	.36	.2532	.33	.1974	.3018	1.192	.0010	.0124	84.8
778	.259	.26	.1606	.21	.1509	.1443	.898	.0010	.0131	73.1
779 ¹	.960	.97	.7647	.99	.2771	1.8400	2.406	.0020	.0116	102.2
780	.924	.93	.7492	.97	.2893	1.7525	2.339	.0020	.0121	97.3
781	.844	.85	.7003	.91	.3007	1.6575	2.367	.0020	.0123	96.5
782	.773	.78	.6459	.84	.3011	1.5350	2.377	.0020	.0123	96.9
783	.728	.73	.6077	.79	.2974	1.4100	2.331	.0020	.0124	95.6
784	.673	.68	.5580	.72	.2908	1.2520	2.244	.0020	.0126	93.1
785	.634	.64	.5213	.68	.2834	1.1300	2.168	.0020	.0128	91.1
786	.573	.58	.4623	.60	.2700	.9838	2.128	.0020	.0126	91.6
787	.527	.53	.4170	.54	.2574	.8364	2.006	.0020	.0129	88.4
788	.470	.47	.3606	.47	.2393	.6804	1.887	.0020	.0128	86.3
789	.352	.36	.2456	.32	.1940	.3820	1.556	.0020	.0132	79.0
790	.254	.26	.1563	.20	.1484	.1821	1.165	.0020	.0139	67.6
791 ¹	.963	.97	.7657	.99	.2757	2.2470	2.935	.0030	.0116	102.1
792	.932	.94	.7532	.98	.2872	2.1660	2.876	.0030	.0121	98.0
793	.690	.70	.5735	.74	.2932	1.5180	2.647	.0030	.0130	89.3
794	.606	.61	.4944	.64	.2776	1.2800	2.589	.0030	.0128	89.7
795	.573	.58	.4623	.60	.2700	1.1800	2.552	.0030	.0129	89.7
796	.526	.53	.4161	.54	.2571	1.0183	2.448	.0030	.0128	88.2
797	.463	.47	.3536	.46	.2370	.8172	2.311	.0030	.0128	86.7
798	.371	.37	.2637	.34	.2020	.5186	1.967	.0030	.0132	79.9
799	.254	.26	.1563	.20	.1484	.2333	1.493	.0030	.0134	70.8
800	.741	.75	.6189	.80	.2988	2.2920	3.704	.0050	.0124	95.8
801	.641	.65	.5279	.68	.2849	1.9170	3.631	.0050	.0122	96.2
802	.613	.62	.5012	.65	.2791	1.7800	3.552	.0050	.0124	95.1
803	.569	.57	.4584	.59	.2690	1.5760	3.438	.0050	.0124	93.8
804	.534	.54	.4240	.55	.2594	1.3750	3.243	.0050	.0127	90.1
805	.485	.49	.3754	.49	.2444	1.1880	3.165	.0050	.0124	90.5
806	.391	.39	.2830	.37	.2102	.7900	2.792	.0050	.0125	86.1
807	.284	.29	.1827	.24	.1631	.4600	2.518	.0050	.0117	88.2
808	.628	.63	.5156	.67	.2822	1.9700	3.821	.0075	.0138	83.1
809	.530	.53	.4200	.54	.2582	1.5900	3.786	.0075	.0131	86.0
810	.453	.46	.3437	.45	.2355	1.2320	3.585	.0075	.0129	85.7
811	.375	.38	.2675	.35	.2036	.8573	3.205	.0075	.0129	82.0
812	.322	.32	.2174	.28	.1808	.5954	2.739	.0075	.0136	74.4
813	.521	.53	.4111	.53	.2556	1.7150	4.172	.0100	.0136	82.5
814	.520	.52	.4101	.53	.2533	1.7425	4.249	.0100	.0134	84.1
815	.478	.48	.3685	.48	.2420	1.4960	4.060	.0100	.0134	82.5
816	.359	.36	.2523	.33	.1970	.9040	3.584	.0100	.0131	80.7
817	.324	.33	.2193	.28	.1817	.6846	3.123	.0100	.0138	73.3
818	.523	.53	.4131	.54	.2517	2.0080	4.860	.0125	.0130	86.6
819	.454	.46	.3447	.45	.2339	1.5900	4.613	.0125	.0130	85.3
820	.354	.36	.2475	.32	.1949	1.0420	4.211	.0125	.0125	85.3
821	.302	.30	.1990	.26	.1716	.8010	4.026	.0125	.0120	86.9
822	.482	.49	.3725	.48	.2433	1.9780	5.310	.0150	.0128	87.9
823	.399	.40	.2908	.38	.2133	1.4080	4.843	.0150	.0127	85.6
824	.301	.30	.1981	.26	.1711	.8510	4.295	.0150	.0122	84.8

¹ These tests used in deriving formulæ 26 and 28.



Figure 1. The Power Spectrum



Figure 2. The Power Spectrum

Fig.1. Concrete Tile Analytical Method using Selected Tests

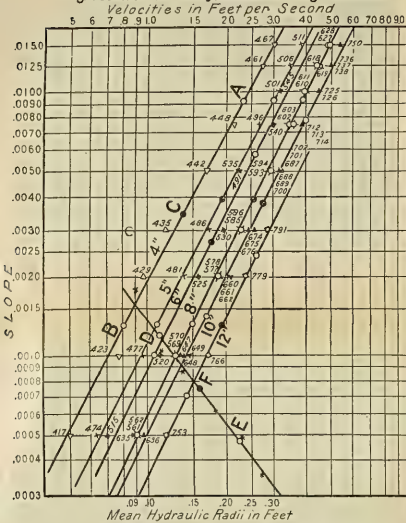


Fig.2. Concrete Tile Graphical Method using Selected Tests

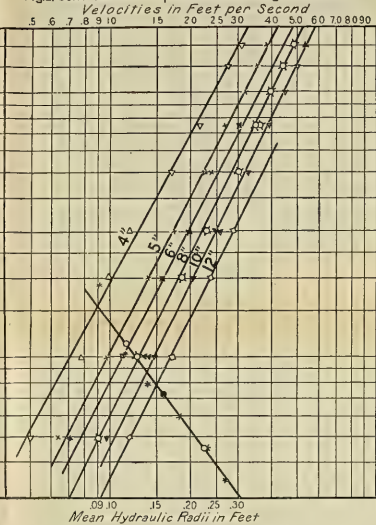


Fig.3. Concrete Tile Flowing Full

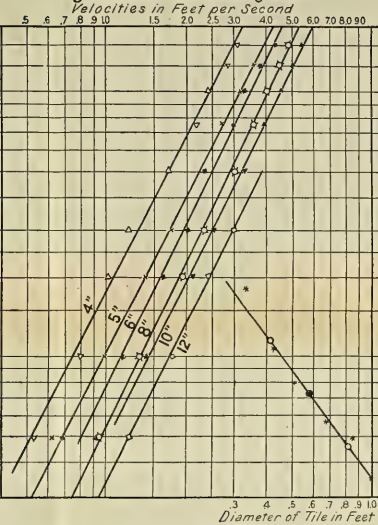


Fig.4. Concrete Tile Flowing .9 Depth

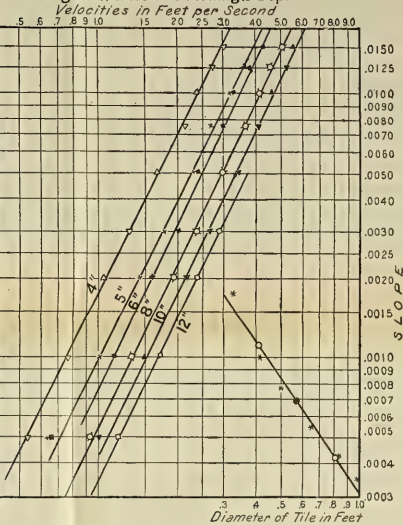


Fig.5. Concrete Tile Flowing .8 Depth

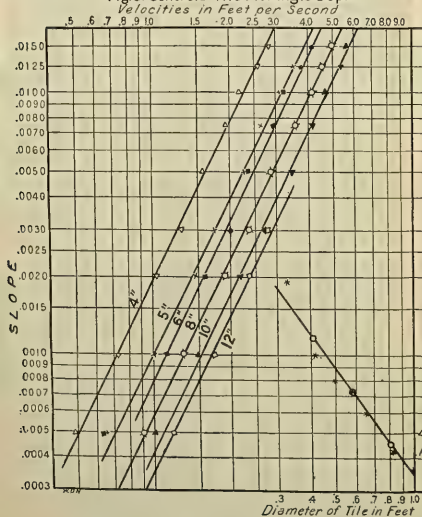


Fig.6. Concrete Tile Flowing .7 Depth

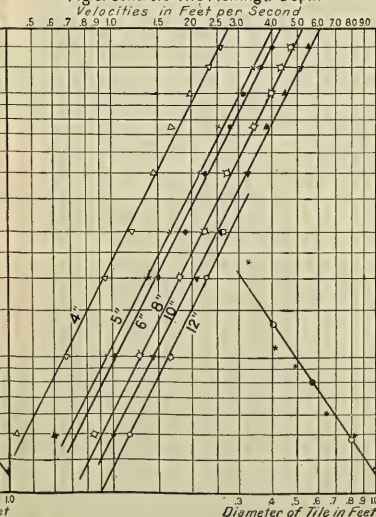


Fig.7. Concrete Tile Flowing .6 Depth

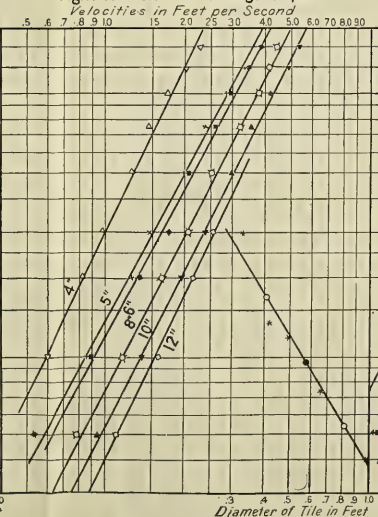


Fig.8. Concrete Tile Flowing .5 Depth

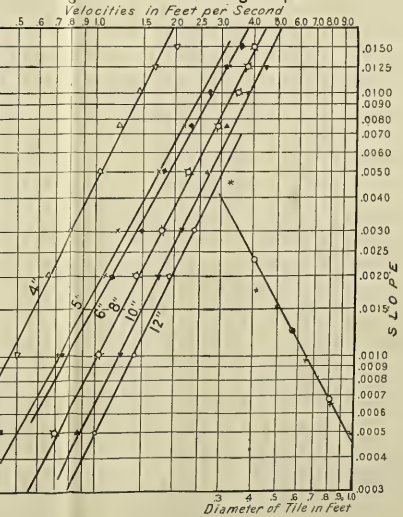


TABLE 5.—*Elements of experiments for clay tile poorly laid.*

10-INCH TILE.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hydraulic radius.	Discharge.	Velocity.	Slope.	Kutter coefficient.	Chezy coefficient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
	<i>Feet.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft. per sec.</i>	<i>Feet per sec.</i>			
825.....	0.805	0.96	0.5423	0.99	0.2355	0.5342	0.985	0.0005	0.0120	90.8
826.....	.795	.95	.5389	.98	.2391	.5679	1.054	.0005	.0116	96.4
827.....	.708	.85	.4957	.90	.2537	.5465	1.103	.0005	.0116	97.9
828.....	.625	.75	.4401	.80	.2520	.4934	1.121	.0005	.0114	99.9
829.....	.524	.63	.3621	.66	.2368	.3780	1.044	.0005	.0116	96.0
830.....	.429	.51	.2837	.51	.2124	.2924	1.031	.0005	.0109	100.0
831.....	.313	.37	.1876	.34	.1704	.1602	.854	.0005	.0111	92.5
832.....	.214	.25	.1110	.20	.1251	.0744	.671	.0005	.0111	81.8
833.....	.836	1.00	.5489	1.00	.2090	.5102	.929	.0005	.0117	90.9
834.....	.791	.95	.5374	.98	.2405	.5390	1.003	.0005	.0120	91.5
835.....	.712	.85	.4981	.91	.2535	.5222	1.048	.0005	.0120	93.1
836.....	.620	.74	.4365	.80	.2514	.4772	1.093	.0005	.0116	97.5
837.....	.532	.64	.3685	.67	.2385	.4093	1.111	.0005	.0111	101.7
838.....	.417	.50	.2736	.50	.2087	.2737	1.000	.0005	.0111	97.9
839.....	.311	.37	.1860	.34	.1696	.1620	.871	.0005	.0109	94.6
840.....	.227	.27	.1206	.22	.1315	.0780	.647	.0005	.0117	79.8
841.....	.831	.99	.5484	.99	.2173	.7510	1.370	.0010	.0118	92.9
842.....	.799	.96	.5403	.98	.2378	.7964	1.474	.0010	.0118	95.6
843.....	.697	.83	.4890	.89	.2541	.7855	1.607	.0010	.0115	100.8
844.....	.628	.75	.4423	.81	.2523	.7180	1.624	.0010	.0113	102.2
845.....	.547	.65	.3806	.69	.2415	.6089	1.600	.0010	.0111	103.0
846.....	.422	.51	.2778	.51	.2103	.4114	1.481	.0010	.0109	102.1
847.....	.324	.39	.1966	.36	.1749	.2656	1.351	.0010	.0105	102.2
848.....	.234	.28	.1257	.23	.1349	.1393	1.108	.0010	.0105	95.4
849.....	.835	1.00	.5488	1.00	.2106	.7570	1.379	.0010	.0115	95.0
850.....	.786	.94	.5355	.98	.2421	.7720	1.442	.0010	.0121	92.7
851.....	.697	.83	.4890	.89	.2541	.7300	1.493	.0010	.0121	93.7
852.....	.619	.74	.4357	.79	.2513	.6720	1.542	.0010	.0117	97.3
853.....	.537	.64	.3726	.68	.2395	.5465	1.467	.0010	.0119	94.8
854.....	.433	.52	.2870	.52	.2136	.3720	1.296	.0010	.0122	88.7
855.....	.338	.40	.2080	.38	.1805	.2222	1.068	.0010	.0128	79.5
856.....	.221	.26	.1161	.21	.1285	.0768	.662	.0010	.0149	53.4

12-INCH TILE.

1	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hydraulic radius.	Discharge.	Velocity.	Slope.	Kutter coefficient.	Chezy coefficient.
	(d)		(a)		(R)	(Q)	(V)	(s)	(n)	(C)
857.....	0.951	0.96	0.7546	0.99	0.2769	0.9193	1.218	0.0005	0.0112	103.5
858.....	.877	.89	.7173	.94	.2954	.8396	1.171	.0005	.0121	96.3
859.....	.731	.74	.6068	.80	.2965	.6468	1.066	.0005	.0130	87.6
860.....	.643	.65	.5272	.69	.2844	.5342	1.013	.0005	.0132	85.0
861.....	.559	.57	.4466	.59	.2657	.4335	.971	.0005	.0131	84.2
862.....	.463	.47	.3521	.46	.2365	.2814	.799	.0005	.0141	73.5
863.....	.373	.38	.2646	.35	.2025	.1512	.571	.0005	.0166	56.8
864.....	.916	.93	.7392	.97	.2882	1.2640	1.710	.0010	.0117	100.7
865.....	.789	.80	.6548	.86	.2999	1.0450	1.596	.0010	.0126	92.2
866.....	.691	.70	.5714	.75	.2921	.8492	1.486	.0010	.0132	87.0
867.....	.594	.60	.4806	.63	.2742	.6197	1.289	.0010	.0142	77.9
868.....	.483	.49	.3719	.49	.2432	.3760	1.011	.0010	.0159	64.8
869.....	.386	.39	.2771	.36	.2078	.2019	.729	.0010	.0186	50.6
870.....	.972	.99	.7609	.99	.2654	1.7125	2.251	.0020	.0119	97.7
871.....	.926	.94	.7442	.98	.2856	1.6750	2.251	.0020	.0124	94.2
872.....	.799	.81	.6626	.87	.3000	1.3940	2.104	.0020	.0135	85.9
873.....	.664	.67	.5469	.72	.2882	1.0125	1.851	.0020	.0147	77.1
874.....	.573	.58	.4602	.60	.2692	.7435	1.616	.0020	.0156	69.7
875.....	.470	.48	.3591	.47	.2389	.4634	1.291	.0020	.0171	59.1
876.....	.368	.37	.2599	.34	.2005	.2363	.909	.0020	.0200	45.4
877.....	.782	.79	.6493	.85	.2997	1.6475	2.538	.0030	.0136	84.6
878.....	.672	.68	.5542	.73	.2896	1.2700	2.293	.0030	.0145	77.8
879.....	.557	.57	.4447	.58	.2651	.8332	1.874	.0030	.0161	66.5
880.....	.457	.46	.3462	.45	.2344	.5174	1.495	.0030	.0177	56.4
881.....	.360	.37	.2522	.33	.1973	.2737	1.085	.0030	.0202	44.6

TABLE 5.—*Elements of experiments for clay tile poorly laid—Continued.*

12-INCH TILE—Continued.

2	2	3	4	5	6	7	8	9	10	11
Test No.	Depth of flow.	$\frac{d}{D}$	Area of flow.	$\frac{a}{A}$	Hy- draulic radius.	Dis- charge.	Ve- locity.	Slope.	Kutter coeffi- cieno.	Chezy coeffi- cient.
	(<i>d</i>)		(<i>a</i>)		(<i>E</i>)	(<i>Q</i>)	(<i>V</i>)	(<i>s</i>)	(<i>n</i>)	(<i>C</i>)
	<i>Nect.</i>		<i>Sq. ft.</i>		<i>Feet.</i>	<i>Cu. ft.</i> <i>per sec.</i>	<i>Feet</i> <i>per sec.</i>			
882.....	0.756	0.77	0.6280	0.82	0.2987	2.870	2.870	0.0050	0.0152	74.3
883.....	.636	.65	.5207	.68	.2830	1.2925	2.493	.0050	.0164	66.3
884.....	.549	.56	.4368	.57	.2830	.9820	2.248	.0050	.0170	62.0
885.....	.450	.46	.3394	.45	.2320	.5887	1.735	.0050	.0191	50.9
886.....	.356	.36	.2485	.33	.1955	.3231	1.300	.0050	.....	41.6
887.....	.929	.94	.7455	.98	.2847	2.8640	3.842	.0075	.0137	83.1
888.....	.849	.86	.6691	.92	.2982	2.5800	3.691	.0075	.0146	78.0
889.....	.709	.72	.5877	.77	.2941	2.1360	3.635	.0075	.0147	77.4
890.....	.700	.71	.5796	.76	.2931	2.0380	3.516	.0075	.0150	75.0
891.....	.638	.65	.5225	.69	.2834	1.7350	3.321	.0075	.0154	72.0
892.....	.519	.53	.4073	.53	.2544	1.0260	2.519	.0075	.0178	57.7
893.....	.428	.43	.3178	.42	.2240	.6265	1.972	.0075	.0198	48.1

NOTE: Nos. 825 to 832, inclusive, 841 to 843, inclusive, and 857 to 893, inclusive; grade of flume uniform. Nos. 833 to 840, inclusive, and 849 to 856, inclusive; grade of flume undulating.

DISCUSSION OF COMPUTATIONS.

All of the formulæ derived herein are of the exponential type since this seems to be the only form capable of representing the data. It seemed most natural to determine first the relation of velocity to slope, other elements being unchanged. In using for this purpose the same line of tile without disturbing the joints, the most uncertain element in tile observations was removed. The chief remaining difficulty lay in the observations of depth of flow, to secure a constant value for comparison at different slopes. When, for a given size of tile and constant depth of flow, slopes are plotted logarithmically as ordinates against their corresponding velocities as abscissæ, the resulting points are approximately on a straight line. The equation of such a line is of the form,

$$s = mV^z \quad (14)$$

which in logarithmic terms may be written,

$$\log s = \log m + z \log V \quad (15)$$

where m is the intercept on the unity vertical axis, and z is the slope of the line, i. e., the tangent of the angle which it makes with the axis of V .

For several different sizes of tile of the same material, the values of m follow the equation,

$$m = eD^x \quad (16)$$

Substituting in formula 14,

$$s = eD^x V^z \quad (17)$$

This expressed in logarithmic terms is

$$\log s = \log e + x \log D + z \log V \quad (18)$$

FORMULÆ FOR TILE FLOWING FULL.

In deriving the various formulæ, both analytical and graphical methods were used in order to insure accuracy. Figure 1 of Plate X shows the results obtained by the analytical method for the concrete tile. This diagram was obtained by plotting the velocities of all the selected experiments in Table 4¹ against their respective slopes. The centers of gravity of the various points for each size of tile were plotted, after being calculated as outlined below. Straight lines were drawn through these centers of gravity for each size. Thus a series of approximately parallel lines was obtained. It should be noted that in using the analytical method, equal weight is given to the least velocity and the greatest velocity. The slopes and intercepts of each of the lines on this diagram were determined analytically.

The following description gives the methods of derivation. Taking the experiments in which the tile were approximately full, shown in Table 4,¹ the center of gravity of all the points belonging to any one size of tile was determined as follows: The antilogarithm of the mean value of the logarithms of the various velocities gave the velocity coordinate of the center of gravity; the slope coordinate of the center of gravity was found in a similar manner. This point, *C*, shown by a solid circle (Pl. X, fig. 1), divides the plotted points into two groups. The center of gravity of the two groups separated by the principal center of gravity must also be found. These points, *A* and *B*, are shown by open circles. Having these two points, the equation of the line for that particular size of tile and depth of flow can be readily determined, as shown by the following sample calculation for 4-inch concrete tile:

Let *C* = center of gravity of the whole group.

A = center of gravity of the part of the group above *C*.

B = center of gravity of the part of the group below *C*.

¹The serial numbers of these selected experiments are indicated in Tables 3 and 4.

Let C_v, A_v, B_v , and C_s, A_s, B_s , be the V and s coordinates, respectively, of the above centers of gravity. The calculations for these coordinates are as follows:

No.	V.	s.	Log V.		Log s.	
417	0.5041	0.0005	9.702517	Sum=39.672744 Mean=9.918186= B_v Antilog B_v =0.8283	(6.698970)	Sum=28.477121 Mean=7.119280= B_s Antilog B_s =0.0013181
423	.7847	.0010	9.894704		(7.000000)	
429	.9884	.0020	9.994933		(7.301030)	
435	1.204	.0030	10.080590		(7.477121)	
442	1.697	.005	10.229682	Sum=41.493438 Mean=10.373359= A_v Antilog A_v =2.3624	(7.698970)	Sum=31.847032 Mean=7.961758= A_s Antilog A_s =0.0091571
448	2.1676	.0075	10.335979		(7.875061)	
461	2.7711	.0125	10.442652		(8.096910)	
467	3.0558	.0150	10.485125		(8.176091)	
Sum=81.166182			Sum=60.324153			
Mean=10.1457727= C_v			Mean=7.540519= C_s			
Antilog C_v =1.39885			Antilog C_s =0.0034715			

$$\begin{aligned}
 A_v - C_v &= 10.373359 - 10.1457727 = 0.227586 \\
 C_v - B_v &= 10.1457727 - 9.918186 = .227587 \\
 A_s - C_s &= 7.961758 - 7.540519 = .421239 \\
 C_s - B_s &= 7.540519 - 7.119280 = .421239
 \end{aligned}$$

Since

$$\frac{A_v - C_v}{C_v - B_v} = \frac{A_s - C_s}{C_s - B_s}$$

the three points, A , C , and B are in a straight line, which checks the accuracy of the work (see American Civil Engineers' Pocketbook, second edition, p. 848).

The exponent, z , of V in formula 14, is the inclination of the line ACB , and is equal to the tangent of the angle formed by the line and the unity axis of V .

$$\frac{A_s - B_s}{A_v - B_v} = \frac{0.842478}{0.455173} = 1.8509 = z$$

The intercept, m , is determined as follows from equation 15, using the coordinates of the center of gravity, C :

$$\begin{aligned}
 \log m &= \log s - z \log V \\
 &= C_s - z C_v \\
 &= 7.540519 - 1.8509 \times 10.1457727 = 7.270709 \\
 \text{and } m &= 0.0018651.
 \end{aligned} \tag{19}$$

The exponent of V and the value of m are found in the same manner for the other sizes of both concrete and clay tile, running nearly full. These values are shown in column 7 of Table 6. This table gives the formula derived as explained above for each size of tile as well as the range of velocities used in the derivation.

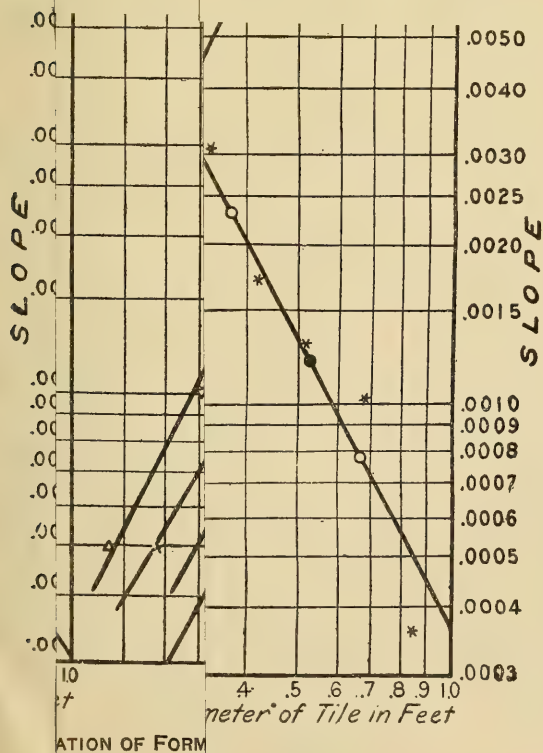


Fig. 1. Clay Tile Analytical Method using Selected Tests

Fig. 2. Clay Tile Graphical Method using Selected Tests

Fig. 3. Clay Tile Flowing Full

Fig. 4. Clay Tile Flowing .9 Depth

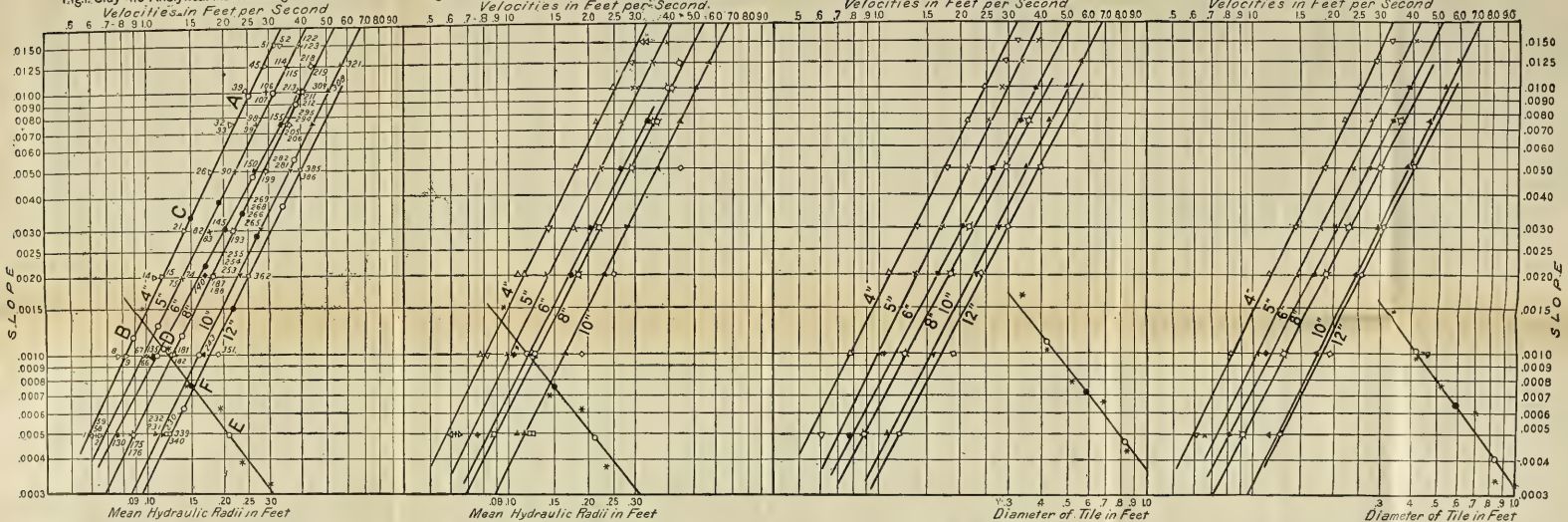
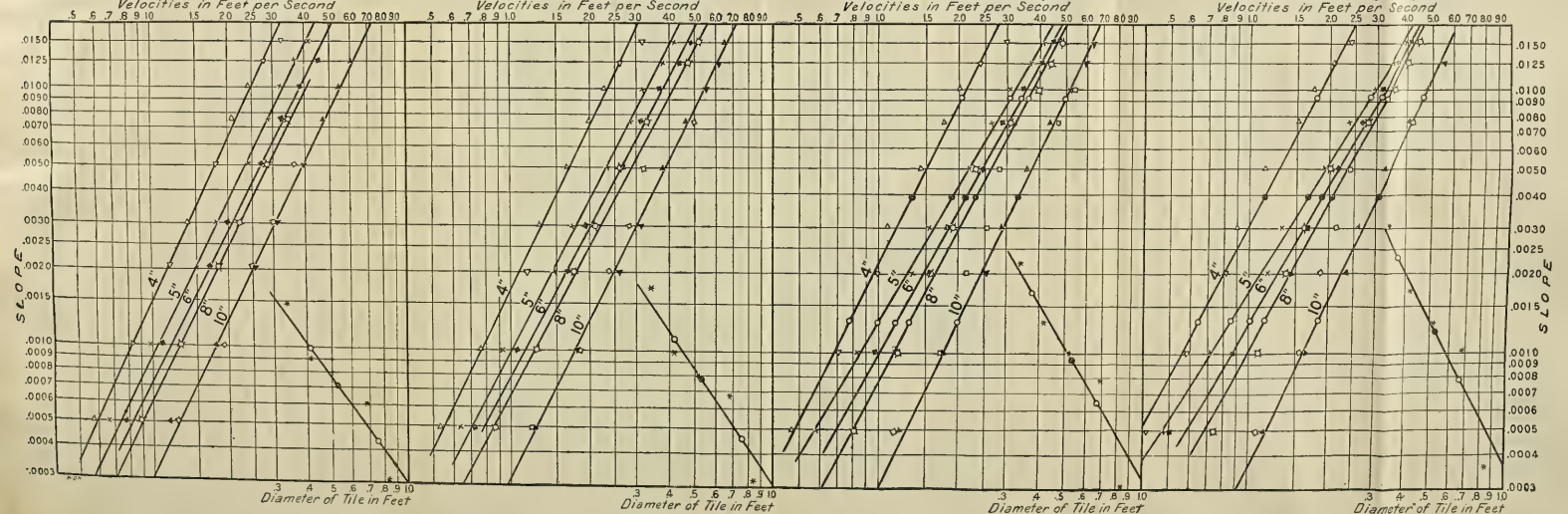


Fig. 5. Clay Tile Flowing .8 Depth

Fig. 6. Clay Tile Flowing .7 Depth

Fig. 7. Clay Tile Flowing .6 Depth

Fig. 8. Clay Tile Flowing .5 Depth



CURVES USED IN THE DERIVATION OF FORMULAE FOR CLAY TILE.

TABLE 6.—*Individual tile formulæ and revised intercept values.*

1	2	3	4	5	6	7	8
Tile.				Velocity.	Number of observations.	Formulæ derived separately for each tile size.	Revised intercept values m' .
Kind.	Nominal size.	Actual average diameter.	Area of bore.				
	<i>Inches.</i>	<i>Feet.</i>	<i>Sq. feet.</i>	<i>Feet per second.</i>			
Hard-burned clay.	4	0.3398	0.0907	0.607 to 3.328	14	$s=0.0014797 \sqrt{V^{2.0265}}$	0.0015185
Do.	5	.4193	.1381	.634 to 4.030	17	$s=.0010494 \sqrt{V^{1.9729}}$	.0010524
Soft-burned clay.	6	.5184	.2111	.765 to 3.368	6	$s=.000819 \sqrt{V^{1.8201}}$	.000761
Hard-burned clay.	8	.685	.3685	.893 to 4.423	15	$s=.000617 \sqrt{V^{1.9914}}$	.0006297
Vitrified.	10	.836	.5489	1.168 to 5.717	18	$s=.000384 \sqrt{V^{1.9918}}$	.0003927
Do.	12	.9857	.7631	1.176 to 4.002	6	$s=.0003185 \sqrt{V^{1.9907}}$	.0003241
Concrete.	4	.3280	.0845	.504 to 3.056	8	$s=.0018651 \sqrt{V^{1.8609}}$	.0017954
Do.	5	.4127	.1338	.640 to 3.891	9	$s=.001077 \sqrt{V^{1.9183}}$	.0010444
Do.	6	.4970	.1940	.705 to 3.274	7	$s=.000856 \sqrt{V^{2.0104}}$	.0008791
Do.	8	.6585	.3406	.914 to 4.959	18	$s=.0005674 \sqrt{V^{2.0373}}$	.0006079
Do.	10	.8274	.5377	.898 to 5.486	26	$s=.0005003 \sqrt{V^{1.9632}}$	.0004997
Do.	12	.9915	.7721	1.183 to 2.935	4	$s=.0003449 \sqrt{V^{2.0059}}$	.0003546

Since for the same kind of tile the exponents V vary for the different sizes, the mean of the exponents has been taken as correct; thus,

For clay tile, $z=1.96859$.

For concrete tile, $z=1.96433$.

Using these mean values of z instead of the values derived for each separate size of tile, new values, m' , were computed for the intercepts on the unity vertical axis, as follows:

$$\text{For clay tile, } \log m' = \log s - 1.96859 \log V \quad (20)$$

$$\text{For concrete tile, } \log m' = \log s - 1.96433 \log V \quad (21)$$

These values of m' are given in column 8 of Table 6.

To introduce the mean hydraulic radius into the formulæ, the relation of the values of m' to the hydraulic radii for the different sizes of concrete tile is represented by the formula,

$$m' = e R^x \quad (22)$$

in which e and x are determined analytically, by a method similar to that previously explained, as follows:

Tile size.	Mean hydraulic radius R .	Intercept values m' .	$\log R$.	$\log m'$.
<i>Inches.</i>	<i>Feet.</i>			
4	0.0915	0.0017954	8.96142	Sum=27.16319
5	.1154	.0010444	9.06221	Mean=9.05439= D_r
6	.1379	.0008791	9.13956	Antilog $D_r=0.1133$
8	.1840	.0006079	9.26482	Sum=28.0655
10	.2316	.0004997	9.36474	Mean=9.35519= E_r
12	.2729	.0003546	9.43600	Antilog $E_r=0.2265$
			Sum=55.22875	Sum=41.249376
			Mean= 9.20479= F_r	Mean= 6.874896= F_m'
			Antilog $F_r=0.1602$	Antilog $F_m'=0.00074971$

The line representing equation 22 is shown in figure 1 of Plate X. The mean hydraulic radii in the above computations were obtained by averaging the hydraulic radii for the selected tests in Table 4 for each size of tile, and not by using $\frac{D}{4}$, because these radii are for tests varying from 95 per cent full to full. The mean hydraulic radii have been plotted as abscissæ with their respective revised intercept values as ordinates. These points are designated in the figure by stars. The centers of gravity as computed above have also been plotted, and a line drawn through them. Substituting in equation 22, transposing, and using the center of gravity just computed,

$$\begin{aligned}\log e &= \log m' - (-1.3128) \log R \\ &= 6.874896 + 1.3128 \times 9.20479 \\ \text{and } e &= 0.00006775\end{aligned}\tag{23}$$

Thus

$$m' = 0.00006775 R^{-1.3128}\tag{24}$$

where 0.00006775 is the intercept on the line $R = 1$, and -1.3128 is the inclination of the line to the horizontal axis. The logarithmic diagram showing the development of the line for equation 24 is shown in figure 1 of Plate X. A similar line for clay tile is shown in figure 1 of Plate XI.

Substituting equation 24 and the mean value of z (p. 40) in the general formula 17, this general equation is now obtained for concrete tile:

$$\begin{aligned}s &= 0.00006775 R^{-1.3128} V^{1.96433} \\ &= \frac{0.00006775 V^{1.96433}}{R^{1.3128}}\end{aligned}\tag{25}$$

From this, solving for V , we get

$$V = 132.5 R^{0.668} s^{0.509}\tag{26}$$

which is the formula derived analytically, using the mean hydraulic radii for the selected experiments for each size of concrete tile in Table 4.

In a like manner, the formula as derived analytically for clay tile was found to be

$$V = 134.7 R^{0.669} s^{0.508}\tag{27}$$

The data used in deriving equation 27 for clay tile are shown on figure 1 of Plate XI. This diagram has been prepared similarly to the diagram in figure 1 of Plate X, except that the values used are from the selected tests in Table 3, for clay tile.

Formulae 26 and 27 were derived by the analytical method, using only experiments with the tile flowing from 95 per cent full to full,

but not under pressure. In order to derive a formula graphically, using the same data as those from which equation 26 was derived analytically, a separate diagram was necessary. This diagram (Pl. X, fig. 2) was obtained by plotting the velocities used in figure 1 of Plate X as abscissæ, against their respective slopes as ordinates, just as in figure 1. Straight lines were drawn through each set of symbols, averaging the points by eye. Although these lines were not intentionally drawn parallel, it will be seen that they are practically so. The slopes of these lines were determined by scale, and the intercepts of the various lines with the unity vertical axis were read from the diagram. The inclination and location of the line involving the mean hydraulic radii and the intercepts were determined analytically. The formula as derived graphically for concrete tile is

$$V = 138.5 R^{0.680} s^{0.510} \quad (28)$$

It should be noted that the exponents of s are the same in equations 26 and 28, while the exponents of R and the coefficients preceding R vary slightly.

In a similar manner, the formula for the flow of water in clay tile was derived graphically from the selected experiments in Table 3, this diagram being shown in figure 2 of Plate XI. In this case the inclination and location of the line involving the mean hydraulic radii and the intercepts were also determined analytically. The formula as derived for clay tile is

$$V = 121.4 R^{0.635} s^{0.5} \quad (29)$$

Comparing this formula with equation 27, it will be noted that the exponents of s are practically the same, while the exponents of R as well as the coefficients preceding R vary somewhat. This difference is probably due to the fact that the observations on the 6-inch tile are slightly inconsistent with those on the other sizes, and this discrepancy is treated somewhat differently in the analytical and graphical methods. In the latter method, greater weight was given to the higher velocities than to the lower ones. The diagrams (Pl. XI, figs. 1 and 2) show the variation in the inclination of the lines for the 6-inch tile.

It will be noted that the formula for flow in clay tile, equation 27, was derived analytically. In order to determine the variation in the coefficient, the velocities for the selected experiments (column 8, Table 3), together with their respective hydraulic radii and slopes, were substituted in equation 27 and new coefficients computed. The mean of the coefficients obtained for clay tile was 137.6. Thus the formula for clay tile, using the same exponents for R and s as in equation 27, was found to be

$$V = 137.6 R^{0.669} s^{0.508} \quad (30)$$

In a like manner, the data for the experimental velocities for the selected experiments (Table 4) were substituted in equation 26, and the formula for concrete tile became

$$V = 131 R^{0.668} s^{0.509} \quad (31)$$

Noting how close the exponents of R and s were to $\frac{2}{3}$ and $\frac{1}{2}$, it was deemed advisable to determine what the coefficient would be when using these latter values. For the clay tile, using all the various sizes and lengths of tile, the formula became,

$$V = 136 R^{\frac{2}{3}} s^{\frac{1}{2}} \quad (32)$$

In the case of concrete tile, the data for the 4-inch size show that greater resistance to flow is offered in this size than in the larger sizes. This is clearly shown in the diagram in Plate X as well as in column 10 of Table 4. Therefore, it was decided to eliminate the 4-inch size and use the remainder of the sizes in the derivation of the formula. The formula for concrete tile, then, is

$$V = 138.2 R^{\frac{2}{3}} s^{\frac{1}{2}} \quad (33)$$

None of the previous formulæ were derived from the combined data for both clay and concrete tile. Therefore, it was decided to derive a formula by using the velocities for both clay and concrete tile flowing full as obtained from Plate IX. These velocities were plotted as abscissæ against their respective slopes as ordinates (Pl. XII). The formula derived graphically for both clay and concrete tile is

$$V = 137.96 R^{0.67} s^{0.5} \quad (34)$$

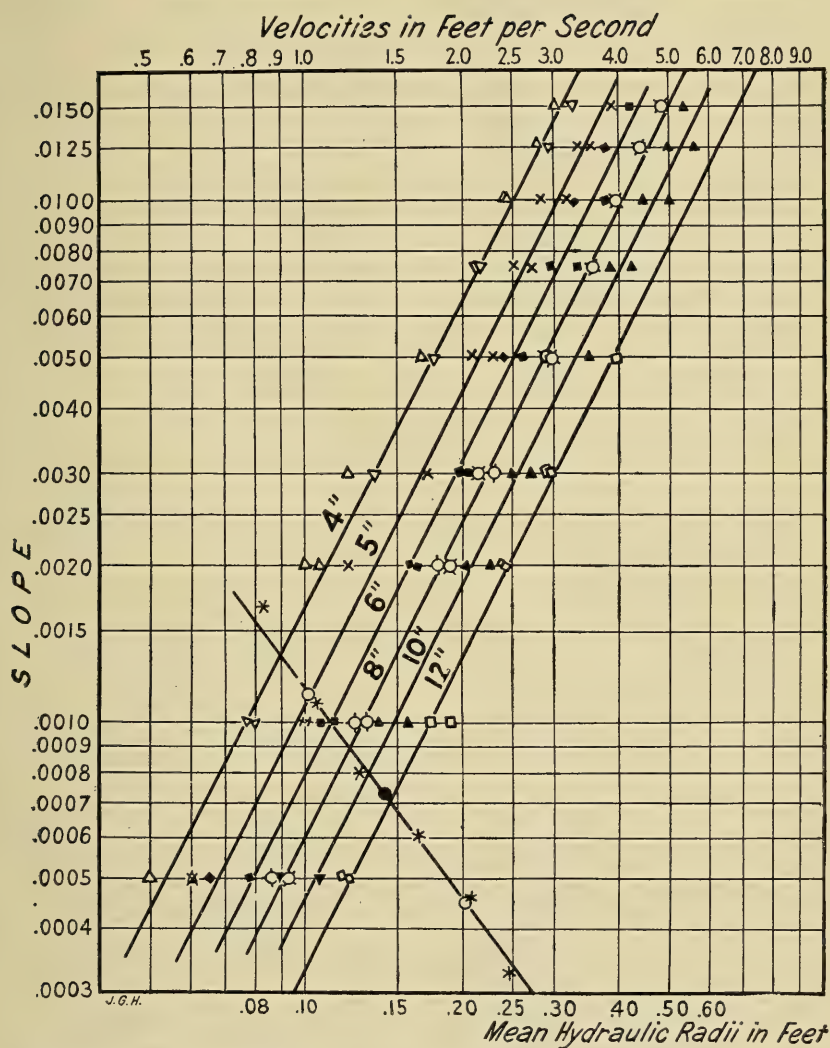
This formula is practically the same as that derived for concrete tile as given in equation 33. Since it was derived from the data for both clay and concrete tile, equation 34 is recommended as the general formula for computing the capacity of tile, merely eliminating the decimal in the coefficient and making the exponents $\frac{2}{3}$ and $\frac{1}{2}$, respectively, thus,

$$V = 138 R^{\frac{2}{3}} s^{\frac{1}{2}} \quad (13)$$

FORMULÆ FOR TILE FLOWING PARTLY FULL

A great many experiments were made at other depths of flow as shown in Tables 3 and 4. These have been plotted and mean curves drawn through the points (see Pl. IX, figs. 1 to 12). The velocities at 0.5, 0.6, 0.7, 0.8, and 0.9 depths and for the tile flowing full were read from these curves and plotted on logarithmic charts as abscissæ, against their respective slopes as ordinates, to determine the equations for flow at these different depths.

Figures 3 to 8, Plate XI, show the studies made of clay tile at various depths of flow. With the exception of the 0.5 and 0.6 depths of flow (figs. 7 and 8), the lines were drawn through the various points by eye, the centers of gravity not being determined analytically.



CURVES USED IN THE DERIVATION OF A FORMULA APPLYING TO BOTH CLAY
AND CONCRETE TILE.

However, for the 0.5 and 0.6 depths of flow the exponents of s were found to be rather high; so for these two depths the centers of gravity of the various sizes of tile were computed analytically, and the exponents of s were found to be the same as the values determined graphically. It should be noted that the diameter of the tile and not the mean hydraulic radius was used in the formulæ derived for various depths of flow. In determining the equation of the line showing the relation of m and the diameter D (equation 16), the centers of gravity were computed lest appreciable error should be introduced in attempting to draw these lines by eye. However, after the lines were drawn through the computed centers of gravity, the slopes of these lines were determined by scale and the intercept was read direct from the diagram.

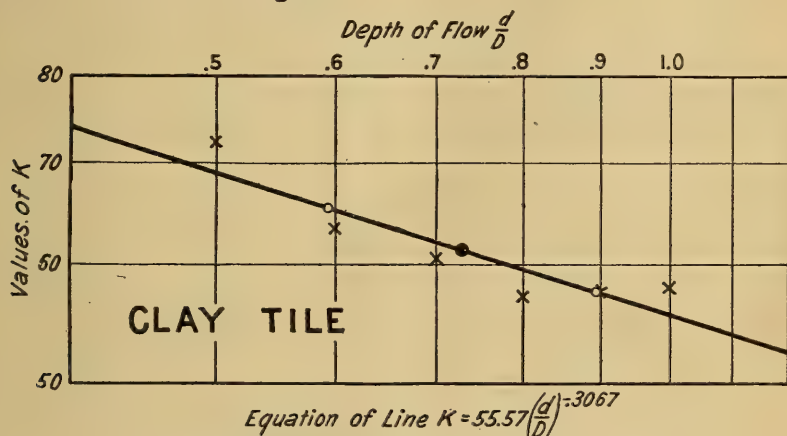


FIG. 1.—Relation of coefficient K to depth of flow in formulæ 35–40.

The formulæ for clay tile as derived from figures 3 to 8, Plate XI, are as follows:

$$\text{For tile flowing full, } V = 57.8 D^{0.662} s^{0.512} \quad (35)$$

$$\text{For tile flowing 0.9 depth, } V = 57.5 D^{0.678} s^{0.502} \quad (36)$$

$$\text{For tile flowing 0.8 depth, } V = 57.1 D^{0.682} s^{0.498} \quad (37)$$

$$\text{For tile flowing 0.7 depth, } V = 60.5 D^{0.756} s^{0.507} \quad (38)$$

$$\text{For tile flowing 0.6 depth, } V = 63.4 D^{0.881} s^{0.518} \quad (39)$$

$$\text{For tile flowing 0.5 depth, } V = 72.2 D^{1.01} s^{0.541} \quad (40)$$

These equations furnish sufficient basis for determining next a general formula to cover every depth of flow. Since in this group of formulæ the exponent of s is about 0.5, each equation is of the form

$$V = K D^{\alpha} s^{0.5} \quad (41)$$

Plotting the values of the coefficient K in formulæ 35 to 40 as ordinates, against their respective depths of flow as abscissæ, an equation involving K and $\frac{d}{D}$ is determined (see text-fig. 1). This equation is found to be

$$K = 55.57 \left(\frac{d}{D}\right)^{-0.3067} \quad (42)$$

In a like manner, plotting values of the exponent of D as ordinates against their respective depths of flow as abscissæ, the equation for the exponent of D for any depth of flow was found to be (see text-fig. 2)

$$\alpha = 0.6284 \left(\frac{d}{D} \right)^{-0.639} \quad (43)$$

Then writing the equation to cover every depth of flow in clay tile, we have

$$V = \frac{55.57}{\left(\frac{d}{D} \right)^{0.3067}} \left[D \right]^{\frac{0.6284}{\left(\frac{d}{D} \right)^{0.639}} s^{0.5}} \quad (44)$$

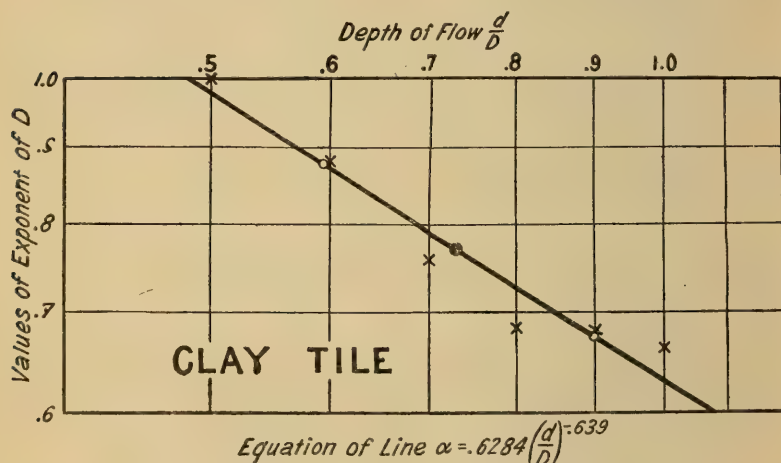


FIG. 2.—Relation of exponent of D to depth of flow in formulæ 35–40.

When $\frac{d}{D}$ equals 1—in other words when the tile is flowing full—and assuming the exponent of s to be 0.5 for all depths of flow,

$$V = 55.57 D^{0.6284} s^{0.5} \quad (45)$$

A study of figures 3 to 8, Plate X, shows that the 4-inch concrete tile appears to have a greater coefficient of roughness than do the larger sizes. This is also indicated in Table 4. Therefore it was decided to eliminate the 4-inch tile and consider only the remaining sizes in deriving a new formula. The formulæ for the concrete tile for the 5, 6, 8, 10, and 12 inch sizes for all depths of flow then become:

$$\text{For tile flowing full, } V = 51.15 D^{0.590} s^{0.496} \quad (46)$$

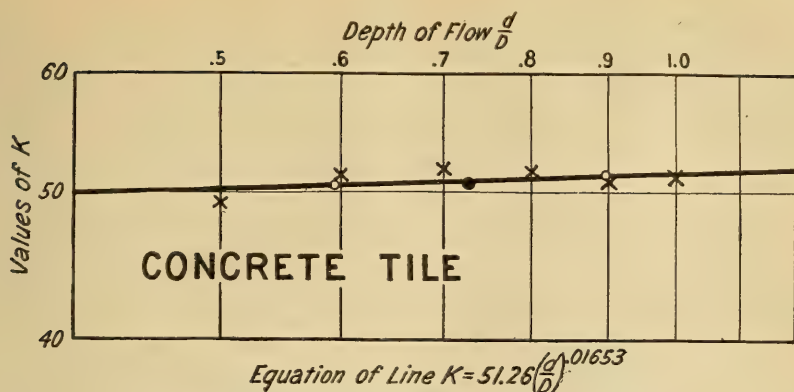
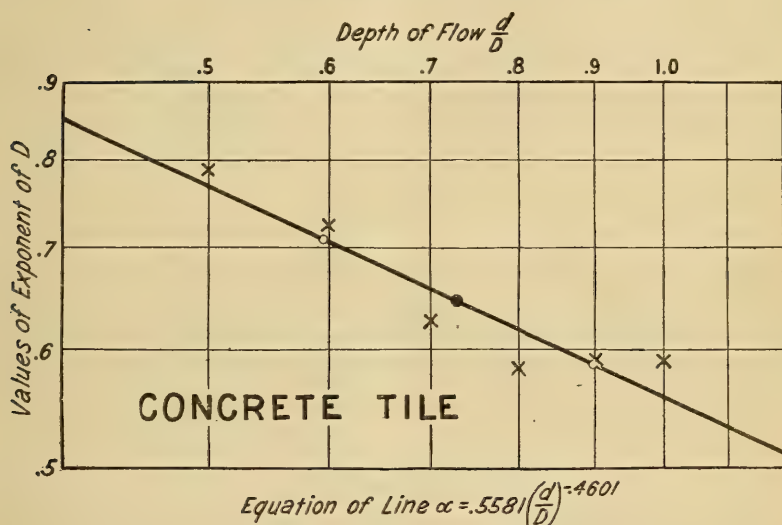
$$\text{for tile flowing 0.9 depth, } V = 50.80 D^{0.589} s^{0.491} \quad (47)$$

$$\text{for tile flowing 0.8 depth, } V = 51.49 D^{0.582} s^{0.496} \quad (48)$$

$$\text{for tile flowing 0.7 depth, } V = 51.93 D^{0.625} s^{0.501} \quad (49)$$

$$\text{for tile flowing 0.6 depth, } V = 51.37 D^{0.723} s^{0.504} \quad (50)$$

$$\text{for tile flowing 0.5 depth, } V = 49.22 D^{0.789} s^{0.510} \quad (51)$$

FIG. 3.—Relation of coefficient K to depth of flow in formulæ 46-51.FIG. 4.—Relation of exponent of D to depth of flow in formulæ 46-51.

The exponent of s in all cases is very nearly 0.5, while the constant K also varies but little. Following the same method as before (see text-figs. 3 and 4) to obtain the formula for any depth of flow,

$$K = 51.26 \left(\frac{d}{D} \right)^{0.01653} \quad (52)$$

and

$$\alpha = 0.5581 \left(\frac{d}{D} \right)^{-0.4601} \quad (53)$$

Thus, the equation for any depth of flow in concrete tile is

$$V = 51.26 \left(\frac{d}{D} \right)^{0.01653} \left[D \right]^{\frac{0.5581}{0.01653}} \left(\frac{d}{D} \right)^{0.4601} s^{0.5} \quad (54)$$

When $\frac{d}{D}$ equals 1 (when the tile is flowing full) and assuming the exponent of s to be 0.5 for all depths of flow,

$$V = 51.26 D^{0.5581} s^{0.5} \quad (55)$$

The similarity of this formula to Prony's formula in equation 7 should be noted.

A formula for the clay tile using only the data on the 5, 6, and 8 inch sizes (1-foot lengths) was derived, as well as a formula for the 10 and 12 inch clay tile (2-foot lengths). These, however, were not deemed of great importance as indicating the effect of joints in the tile line, since an insufficient number of tile sizes were available for consideration.

From a study of the data on the flow in tile running partly full, it will be seen that the velocity does not vary in accordance with the variation of the hydraulic radius. This fact suggested an attempt to derive a formula that does not involve the hydraulic radius, but is of the type,

$$V = \left(\frac{A^\alpha}{P^\beta} \right) s^{0.5} \quad (56)$$

That is, instead of the hydraulic radius, or the area divided by the wetted perimeter, it was recognized that the area might have one exponent and the perimeter a different exponent. A careful study of this type of formula revealed the fact that it would be impracticable.

Another type of formula which was considered was of the form

$$V = k \left(\frac{A}{P + C} \right)^x s^{0.5} \quad (57)$$

where k , x , and C are unknown constants. This type was also considered inadvisable.

Still another formula considered was of the type

$$V = \left(\frac{A}{P + FB} \right)^\beta s^{0.5} \quad (58)$$

where F and β are constants and B is the breadth of the water surface in the tile exposed to the air. This type was investigated quite carefully with the data relating to the concrete tile, but was not considered applicable to the conditions.

From a study of the velocity-depth of flow curves it will be seen that the greatest velocity in a pipe is approximately at 0.8 depth. Theoretically it would be at 0.81 depth. Below this the velocity decreases rapidly with the depth of flow. Observations on the flow in

the tile during the experiments indicated that there is additional resistance to the flow caused by the action of the air on the water surface in tile flowing partly full, to which may be due the decided decrease in the velocity at the partial depths. Therefore it was decided to vary the formula for concrete tile,

$$V = 51 D^{0.56} s^{0.5} \quad (59)$$

by substituting $\frac{A}{fP}$ for D , thus,

$$V = 51 \left(\frac{A}{fP} \right)^{0.56} s^{0.5} \quad (60)$$

and to determine the proper values of f for the various depths of flow. In the formula 60, the values of V , s , A , and P from the experiments (V from Plate IX, the others from Table 4) were used, and the values of f were found to be as follows:

Tile flowing full	1.00
Tile flowing 0.9 depth	1.15
Tile flowing 0.8 depth	1.20
Tile flowing 0.7 depth	1.25
Tile flowing 0.6 depth	1.35
Tile flowing 0.5 depth	1.50

The above discussion is given merely as a method of making allowance for air resistance to flow. Further experiments are considered necessary to establish the necessity of making such allowance.

A comparison of the various formulæ which have here been derived may be made from Table 7. The formulæ have been arranged systematically, so that variations may be noted at a glance. They have been so classified that all involving the hydraulic radius are in one column, while those involving the diameter are in another column. The number opposite each formula refers to the corresponding equation in the text.

TABLE 7.—*Summary of formulae derived.*

	In terms of <i>E</i> .	In terms of <i>D</i> .
<i>Clay tile flowing full.</i>		
Derived analytically, using mean hydraulic radii for selected experiments shown in table 3.	$V = 134.7 R^{0.669} s^{0.508} (27).$	
Derived graphically, using mean hydraulic radii for selected experiments shown in table 3.	$V = 121.4 R^{0.659} s^{0.5} (29).$	
Derived using experimental velocities in column 8, table 3, and working for mean coefficient.	$V = 137.6 R^{0.669} s^{0.508} (30).$	
Derived using velocities from figures 1 to 6, Plate IX, $R^{2/3}$, $s^{1/2}$, and working for mean coefficient.	$V = 136 R^{2/3} s^{1/2} (32).$	$V = 57.8 D^{0.669} s^{0.512} (35).$
Derived graphically, using velocities from figures 1 to 6, Plate IX.		
<i>Clay tile flowing partly full.</i>		
Derived graphically, for tile flowing 0.9 full, using velocities from figures 1 to 6, Plate IX.		$V = 57.5 D^{0.675} s^{0.502} (36).$
Derived graphically, for tile flowing 0.8 full, using velocities from figures 1 to 6, Plate IX.		$V = 57.1 D^{0.682} s^{0.503} (37).$
Derived graphically, for tile flowing 0.7 full, using velocities from figures 1 to 6, Plate IX.		$V = 60.5 D^{0.702} s^{0.507} (38).$
Derived graphically, for tile flowing 0.6 full, using velocities from figures 1 to 6, Plate IX.		$V = 63.4 D^{0.681} s^{0.513} (39).$
Derived graphically, for tile flowing 0.5 full, using velocities from figures 1 to 6, Plate IX.		$V = 72.2 D^{0.711} s^{0.521} (40).$
<i>Concrete tile flowing full.</i>		
Derived analytically, using mean hydraulic radii for selected experiments in table 4.	$V = 132.5 R^{0.683} s^{0.509} (26).$	
Derived graphically, using mean hydraulic radii for selected experiments in table 4.	$V = 138.5 R^{0.680} s^{0.510} (28).$	
Derived using experimental velocities in column 8, table 4, and working for mean coefficient.	$V = 131 R^{0.688} s^{0.509} (31).$	
Derived using velocities from figures 7 to 12, Plate IX, $R^{2/3}$, $s^{1/2}$, omitting 4-inch size, and working for mean coefficient.	$V = 138.2 R^{2/3} s^{1/2} (33).$	$V = 51.2 D^{0.699} s^{0.508} (46).$
Derived graphically, using velocities from figures 7 to 12, Plate IX.		
<i>Concrete tile flowing partly full.</i>		
Derived graphically for tile flowing 0.9 full, using velocities from figures 7 to 12, Plate IX.		$V = 50.8 D^{0.689} s^{0.501} (47).$
Derived graphically for tile flowing 0.8 full, using velocities from figures 7 to 12, Plate IX.		$V = 51.5 D^{0.688} s^{0.503} (48).$
Derived graphically for tile flowing 0.7 full, using velocities from figures 7 to 12, Plate IX.		$V = 51.9 D^{0.682} s^{0.501} (49).$
Derived graphically for tile flowing 0.6 full, using velocities from figures 7 to 12, Plate IX.		$V = 51.4 D^{0.723} s^{0.504} (50).$
Derived graphically for tile flowing 0.5 full, using velocities from figures 7 to 12, Plate IX.		$V = 49.2 D^{0.759} s^{0.510} (51).$
Derived graphically using data for both clay and concrete tile flowing full, using velocities from Plate IX.	$V = 138 R^{2/3} s^{1/2} (13).$	

COMPARISON OF VARIOUS FORMULÆ.

Since from a practical standpoint we are interested only in the tile flowing full, velocities as computed by formula 34 are compared with velocities as taken from figures 1 to 12, Plate IX, for the tile flowing full. These results are shown in Tables 8 and 9. The difference is shown, rather than the ratio, between each two determinations of velocity, in order that the variations in the low velocities shall be given only equal weight with equal variations in the high velocities. To get the average differences given in Tables 8 and 9, the arithmetical sum of the differences is divided by the number of items.

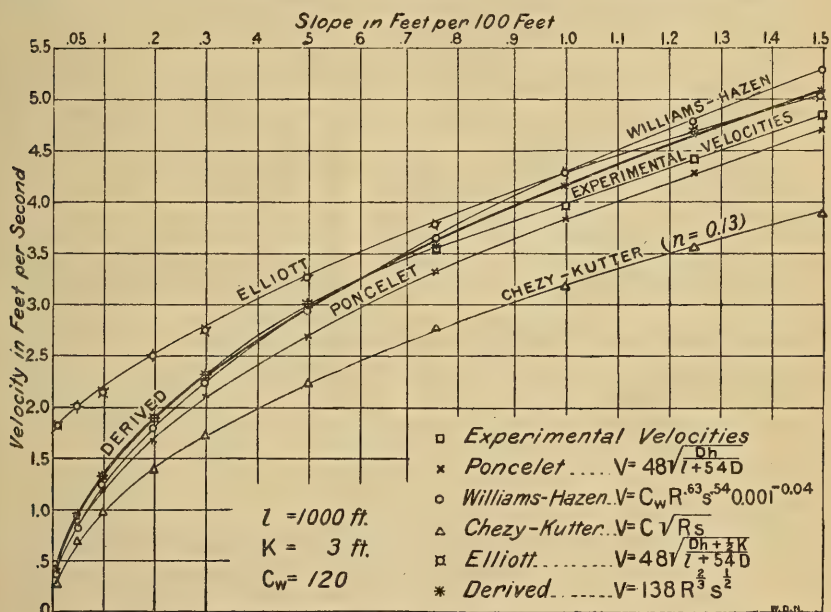


FIG. 5.—Comparison of velocities computed by various formulæ.

Both the Poncelet and the Beardmore formulæ gave greater differences when applied to the experimental data than does the tentative formula, No. 13. The velocities from the curves in Plate IX were substituted in the Williams-Hazen formula, and the average value of C_w , was found to be approximately 120. Using this value in the Williams-Hazen formula, recomputing the velocities, and comparing them with the velocities from the curves in Plate IX, it was found that the average differences were practically the same as the average differences stated at the bottom of Tables 8 and 9.

A comparison of the velocities computed by the various formulæ for one size of tile may be obtained from text-figure 5. This figure shows the velocities for 8-inch tile as computed by the Poncelet, the Williams-Hazen, the Chezy-Kutter (with the coefficient of roughness, n , taken equal to 0.013), the Elliott, and formula 13 herein derived from the experimental data. The observed experimental velocities are also shown.

TABLE 8.—Comparison of velocities for clay tile flowing full.

1	2	3	4	5	1	2	3	4	5
Size of tile.	Grade.	Velocity from curves in Plate IX.	Velocity by formula 34.	Difference between column 3 and column 4.	Size of tile.	Grade.	Velocity from curves in Plate IX.	Velocity by formula 34.	Difference between column 3 and column 4.
<i>Inches.</i>	<i>Per cent.</i>	<i>Ft. per sec.</i>	<i>Ft. per sec.</i>	<i>Ft. per sec.</i>	<i>Inches.</i>	<i>Per cent.</i>	<i>Ft. per sec.</i>	<i>Ft. per sec.</i>	<i>Ft. per sec.</i>
4	0.05	0.60	0.59	-0.01	6	0.75	3.33	3.04	-0.29
	.10	.77	.84	+ .07		1.00	3.78	3.51	- .27
	.20	1.08	1.18	+ .10	8	.05	.87	.95	+ .08
	.30	1.36	1.45	+ .09		.10	1.23	1.34	+ .11
	.50	1.76	1.87	+ .11		.20	1.82	1.89	+ .07
	.75	2.12	2.29	+ .17		.30	2.13	2.32	+ .19
	1.00	2.44	2.64	+ .20		.50	2.92	2.99	+ .07
	1.25	2.93	2.96	+ .03		.75	3.53	3.66	+ .13
	1.50	3.27	3.24	- .03		10	.05	1.06	1.08	+ .02
5	.05	.60	.68	+ .08	.10		1.57	1.52	- .05
	.10	1.02	.96	- .06	.20		2.27	2.16	- .11
	.20	1.35	1.36	+ .01	.30		2.74	2.65	- .09
	.30	1.70	1.67	- .03	.50		3.50	3.42	- .08
	.50	2.11	2.15	+ .04	.75		4.23	4.19	- .04
	.75	2.52	2.64	+ .12	1.00		4.98	4.84	- .14
	1.00	2.83	3.04	+ .21	1.25		5.63	5.40	- .23
	1.25	3.39	3.40	+ .01	12		.05	1.17	1.21	+ .04
	1.50	3.90	3.73	- .17		.10	1.86	1.71	- .15
6	.05	.77	.79	+ .02		.20	2.35	2.41	+ .06
	.10	1.04	1.11	+ .07		.30	2.95	2.96	+ .01
	.20	1.63	1.56	- .07		.50	3.94	3.82	- .12
	.30	2.03	1.92	- .11					
	.50	2.59	2.48	- .11					

Total plus difference.....+2.11
 Total minus difference.....-2.16
 Number of items.....44
 Average difference.....foot per second......097

TABLE 9.—Comparison of velocities for concrete tile flowing full.

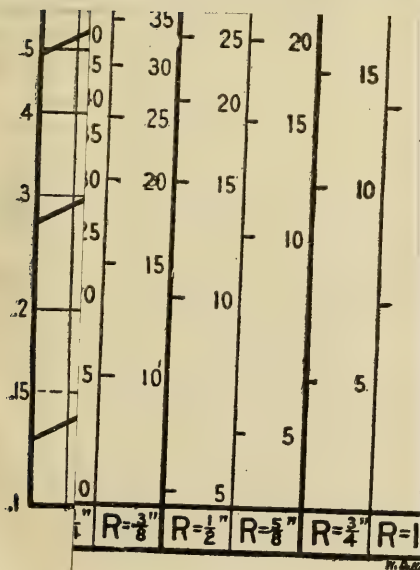
1	2	3	4	5	1	2	3	4	5
Size of tile.	Grade.	Velocity from curves in Plate IX.	Velocity by formula 34.	Difference between column 3 and column 4.	Size of tile.	Grade.	Velocity from curves in Plate IX.	Velocity by formula 34.	Difference between column 3 and column 4.
<i>Inches.</i>	<i>Per cent.</i>	<i>Ft. per sec.</i>	<i>Ft. per sec.</i>	<i>Ft. per sec.</i>	<i>Inches.</i>	<i>Per cent.</i>	<i>Ft. per sec.</i>	<i>Ft. per sec.</i>	<i>Ft. per sec.</i>
4	0.05	0.52	0.58	+0.06	8	0.05	0.92	0.90	-0.02
	.10	.78	.82	+ .04		.10	1.31	1.30	- .01
	.20	.99	1.16	+ .17		.20	1.89	1.84	- .05
	.30	1.18	1.41	+ .23		.30	2.30	2.26	- .04
	.50	1.69	1.83	+ .14		.50	2.99	2.91	- .08
	.75	2.15	2.24	+ .09		.75	3.53	3.57	+ .04
	1.00	2.39	2.58	+ .19		1.00	3.98	4.11	+ .13
	1.25	2.82	2.89	+ .07		1.25	4.42	4.61	+ .19
	1.50	3.06	3.16	+ .10		1.50	4.83	5.04	+ .21
5	.05	.61	.67	+ .06	10	.05	.90	1.07	+ .17
	.10	.97	.95	- .02		.10	1.38	1.52	+ .14
	.20	1.36	1.32	- .04		.20	2.06	2.15	+ .09
	.30	1.71	1.65	- .06		.30	2.47	2.63	+ .16
	.50	2.30	2.13	- .17		.50	3.23	3.39	+ .16
	.75	2.69	2.61	- .08		.75	3.87	4.16	+ .29
	1.00	3.19	3.01	- .18		1.00	4.49	4.80	+ .31
	1.25	3.53	3.37	- .16		1.25	4.99	5.37	+ .38
						1.50	5.37	5.88	+ .51
6	.05	.67	.76	+ .09	12	.05	1.20	1.21	+ .01
	.10	1.13	1.08	- .05		.10	1.72	1.71	- .01
	.20	1.58	1.53	- .05		.20	2.37	2.42	+ .05
	.30	1.97	1.87	- .10		.30	2.93	2.97	+ .04
	.50	2.30	2.41	+ .11					
	.75	2.95	2.95	+ .00					
	1.00	3.26	3.41	+ .15					
	1.25	3.77	3.81	+ .04					
	1.50	4.28	4.18	- .10					

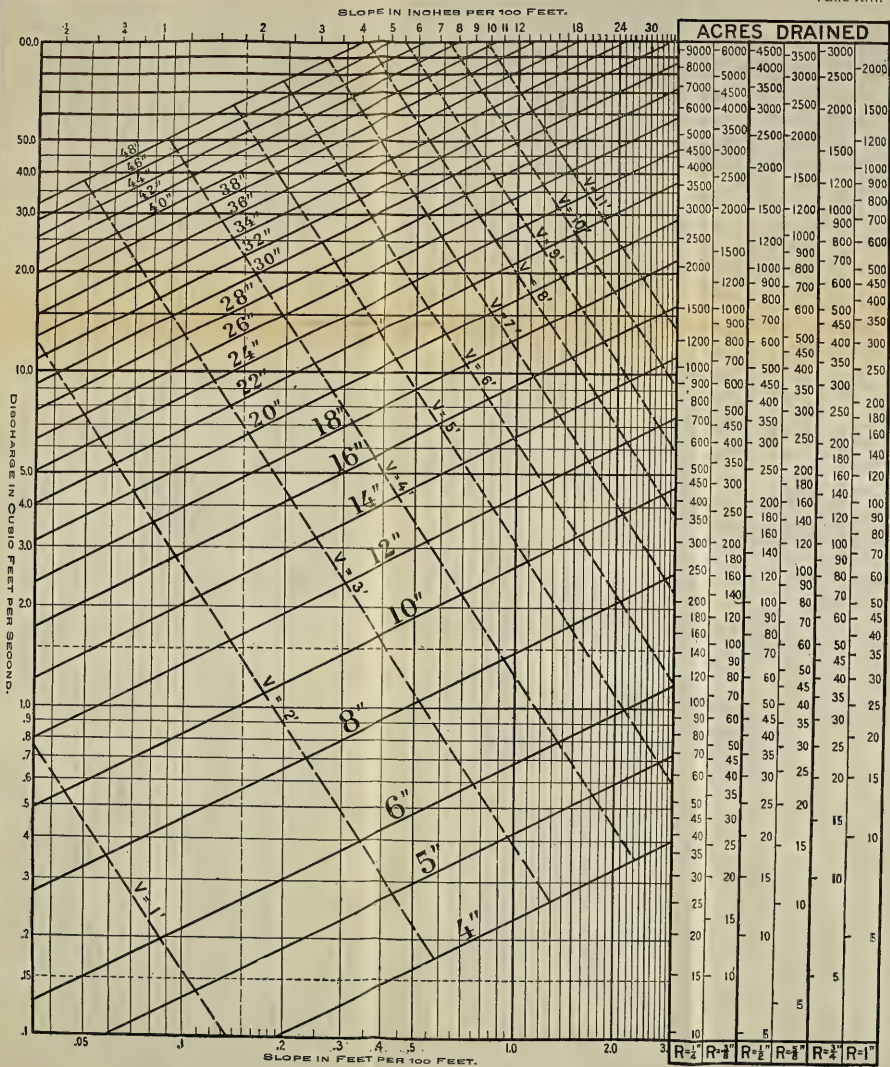
Total plus difference.....+4.42
 Total minus difference.....-1.22
 Number of items.....48
 Average difference.....foot per second......117

CORRECTION

In Bulletin 854 of the United States Department of Agriculture, entitled "The Flow of Water in Drain Tile," the formula given in the legend at the bottom of Plate XIII (facing page 48) should read:

$$V = 138 R^{\frac{3}{2}} S^{\frac{1}{2}}$$





Equation 13 is tentatively offered for use in computing the capacity of tile drains, though with full recognition of the fact that further experiments are necessary to determine its applicability to tile of sizes larger than those used in these experiments. Additional data also are desirable to determine whether the variation in length of the individual tiles is an important item to consider in the derivation of a formula.

For convenience in quickly determining the number of acres drained, for each size of tile and for various rates of run-off, Plate XIII has been prepared from formula 13. Several velocity curves are also shown for use in determining approximately the velocity of flow.

LOSS OF HEAD IN CATCH-BASINS.

To actually determine the loss of head resulting from the installation of a surface inlet or catch-basin in a tile line, experiments were made on 8-inch clay tile at three different grades, 0.2, 0.75, and 1.50 feet in 100 feet, with differences of 0.1, 0.2, and 0.3 foot between the elevations of the inlet and the outlet tiles.

The catch-basin was made by inserting in the flume two wooden bulkheads 4 feet apart. The space between the bulkheads was cleared of tile and earth and thus formed a basin 2 feet wide by 4 feet long. The inlet and outlet tiles extended through the respective bulkheads. A piezometer was installed at the outlet of the catch-basin, another at a point 2 feet below the outlet, and a third at a point 2 feet below the second. Tests were made with and without the use of a 12 to 8 inch reducer at the outlet of the catch-basin. This reducer actually consisted of two sewer-pipe reducers (12 to 10 inch and 10 to 8 inch), each 2 feet long. When the reducer was used the middle piezometer was omitted.

TABLE 10.—*Effect of reducers on the loss of head at outlets of catch-basins.*

Drop in catch- basin.	Grade of tile.	Elevation of water surface without reducers.				Elevation of water surface with reducers.			Head saved by use of reducers.
		In catch- basin.	2 feet below catch- basin.	4 feet below catch- basin.	Loss of head.	In catch- basin.	4 feet below catch- basin.	Loss of head.	
<i>Foot.</i>	<i>Per cent.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>
0.3	0.20	0.46	0.44	0.41	0.05	0.45	0.41	0.04	0.01
		.84	.79	.77	.07	.74	.73	.01	.06
		.58	.57	.45	.13	.56	.52	.04	.09
	.75	.97	.83	.83	.14	.81	.80	.01	.13
		.65	.53	.49	.16	.64	.53	.11	.05
		.78	.66	.64	.14	.76	.76	.00	.14
	1.50	.46	.46	.45	.01	.44	.43	.01	.00
		.83	.79	.78	.05	.75	.74	.01	.04
		.53	.53	.52	.01	.53	.52	.01	.00
	.2	.76	.74	.74	.02	.74	.74	.00	.02
		.67	.65	.53	.14	.60	.56	.04	.10
		1.15	1.02	.80	.35	.82	.77	.05	.30
.1	.20	.44	.43	.43	.01	.45	.43	.02	—
		.79	.73	.73	.06	.76	.73	.03	.03
		.56	.48	.43	.13	.54	.45	.09	.04
	.75	.89	.68	.66	.23	.80	.70	.10	.13
		.68	.60	.56	.12	.65	.56	.09	.03
		1.11	.80	.78	.33	.88	.76	.12	.21

The results of these observations are shown in Table 10. The data indicate that the use of reducers with tile flowing approximately full reduces the loss of head to practically nothing, while with tile flowing half full some loss of head occurs. Without reducers, the loss of head decreases with the decrease in slope. The variation in drop in the catch-basin did not materially affect the loss of head, which seems to be about equal to the grade through 15 feet length of drain.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 855

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief



Washington, D. C.

PROFESSIONAL PAPER

May 6, 1920

SAPONIFIED CRESOL SOLUTIONS

By JACOB M. SCHAFER, *Junior Chemist, Biochemic Division*

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Observations on speed of dilution.....	3	Summary.....	5

This paper describes a series of experiments undertaken with the object of preparing a saponified cresol solution which would be cheaper and at the same time no less effective as a disinfectant than those at present in use. Such a product should contain the usual 50 per cent cresol with the necessary quantity of soap to insure complete solubility in water and should meet the following requirements:

The product shall remain a homogeneous liquid when cooled to 32° F. It shall contain substantially no free oil, fatty acid, or excess alkali. It shall be readily soluble in cold distilled water; the solution shall be practically clear and shall contain no globules of undissolved oil or cresylic acid.¹

By stating the qualifications of a good finished product the Bureau of Animal Industry has safeguarded itself and at the same time allowed the manufacturer to mix the necessary ingredients in the manner he finds most economical.

Disinfectants made with cresylic acid and rosin soap have been objected to because they become cloudy when diluted with water. In the case of a cresol-rosin soap solution diluted with water to a 3 per cent solution and exposed in a flask to the air, it has been found that the clouding is due to the hydrolysis of the rosin soap and the absorption of carbon dioxide from the air, the rosin being precipitated at first in finely divided particles. After a few days these particles commence to agglomerate and settle to the bottom; finally, after about two weeks, equilibrium is reached, the solution clears, and shows a good deal of rosin in a mass at the bottom of the

¹ U. S. Bureau of Animal Industry Order 263.

flask. Further dilution increases the hydrolysis and subsequently brings on additional clouding.

PROPERTIES OF MIXTURES WITH ROSIN SOAP

It was found that soaps of some vegetable oils, fatty acids, and fish oil (menhaden) when mixed with rosin soap had the property of retarding the clouding and precipitating of rosin in rosin-soap-cresol solutions. A number of different soaps were tried as ingredients of 50 per cent saponified cresol solutions. Those tried were rosin soap, soy-bean-oil soap, linseed-oil soap, oleic-acid soap, fish-oil soap, rosin-soy-bean-oil soap, rosin-linseed-oil soap, rosin-oleic-acid soap, and rosin-fish-oil soap. These soaps were used in proportions equivalent to 28 per cent linseed oil in the finished product.

Saponified cresol solutions were made with rosin soap, the sodium hydroxid varying from enough to saponify the rosin to an excess of 20 per cent. On dilution to a 3 per cent solution with distilled water the saponified cresol solution containing no excess alkali dissolved quickly and clouded after about 3 minutes; beyond 5 per cent excess alkali the solutions dissolved more slowly and clouded after about 3 minutes. Increasing the excess of alkali beyond 5 per cent has therefore no beneficial results, and at the same time this excess combines with the cresol, lowering the coefficient of the finished product.

Saponified cresol solutions were prepared by mixing rosin and soy-bean oil, saponifying the mixture with just enough sodium-hydroxid solution and then adding the cresol. These had the same properties as saponified cresol solutions containing varying proportions of rosin soap to soy-bean-oil soap prepared by mixing a saponified cresol solution containing soy-bean-oil soap and one containing rosin soap.

Analysis of the soy-bean oil saponified cresol solution:

Phenols, 53.5 per cent.

Fatty acids + unsaponifiable matter equivalent to 28 per cent oil.

Total alkali as sodium hydroxid, 4.0 per cent.

Water not determined.

Analysis of the rosin saponified cresol solution:

Phenols, 53.5 per cent.

Rosin acids (equivalent to 33.6 per cent rosin or 28 per cent oil), 30.2 per cent.

Total alkali as sodium hydroxid, 4.0 per cent.

Water not determined.

The table following gives the proportion of soy-bean-oil soap to rosin soap in the total soap present in these saponified cresol solutions. Under the heading "Remarks" are recorded the results of adding the saponified cresol solutions to distilled water at 20° C. to form 3 per cent solutions.

Soy-bean-oil soap.	Rosin soap.	Remarks.
<i>Per cent.</i>	<i>Per cent.</i>	
10	90	Shows faint clouding after 1½ hours.
20	80	Shows faint clouding after 2½ hours.
25	75	Clear after 5 hours; faint cloud at 24 hours.
30	70	Clear at 24 hours (sometimes faintly cloudy).
40	60	Faint cloud after 48 hours.
50	50	Clear at 7 days.
60	40	Clear after 7 days.
70	30	Do.
80	20	Do.
90	10	Do.

OBSERVATIONS ON SPEED OF DILUTION

All dilute clear and more quickly than the saponified cresol solution prepared from soy-bean oil only; those containing the larger proportion of soy-bean oil to rosin more nearly approach straight soy-bean oil in speed of dilution. None separate or solidify when held at 32° F. All are more viscous than the straight soy-bean oil preparation. Amounts of sodium hydroxid up to 20 per cent in excess of that theoretically required in similar preparations retard the speed of dilution and only to a slight extent the clouding.

Three per cent dilutions were made, using tap water instead of distilled water. The saponified cresol solution made with straight soy-bean-oil soap clouded immediately. The soy-bean oil 10 per cent, rosin 90 per cent, clouded after about one-half hour. The soy-bean oil 30 per cent, rosin 70 per cent, was clear at 5 hours but cloudy at 24 hours. Amounts of sodium hydroxid up to 20 per cent in excess of that theoretically required in preparations like these had little effect on their tendency to cloud.

A saponified cresol solution made by mixing a saponified cresol solution containing linseed-oil soap and the solution containing the rosin soap so as to contain a soap equivalent to linseed oil 25 per cent, rosin 75 per cent, behaves very much like that made with soy-bean oil 25 per cent, rosin 75 per cent.

A saponified cresol solution made by mixing a solution containing fish-oil (menhaden) soap and the solution containing the rosin soap so as to contain a soap equivalent to linseed oil 25 per cent, rosin 75 per cent, behaves very much like that made with soy-bean oil 25 per cent, rosin 75 per cent.

A saponified cresol solution containing 7 per cent by weight of soy-bean oil as soap and 25 per cent by weight of rosin (containing 90 per cent rosin acid) as soap will closely approximate a saponified cresol solution made by using a mixture of 25 per cent soy-bean-oil soap and 75 per cent rosin soap. The figures are convenient to use and a preparation made with this proportion of oil to rosin should be just as easy to manufacture as the saponified cresol solutions at pres-

ent in use. It may be easier, in fact, because the presence of rosin hastens the saponification of the oil.

The mean combining weight of rosin was taken as 346.¹

Saponification value of 1 gram of linseed oil in terms of sodium hydroxid equals 0.137 gram.

$28 \times 0.137 = 3.83$ grams sodium hydroxid needed to saponify 28 grams oil.

$3.83 \times \frac{346}{40} = 33.13$ grams rosin equivalent to 28 grams oil.

$33.13 \times \frac{3}{4} = 24.82$ per cent rosin (approximately 25 per cent).

This rosin-soy-bean-oil-cresol solution remains a homogeneous liquid when cooled to 32° F. It is readily soluble in distilled water. The freshly prepared 3 per cent solution is clear and remains clear for more than 1 hour. The rosin-linseed-oil-cresol solution, rosin-oleic-acid-cresol solution, rosin-fish-oil-cresol solution containing 25 parts by weight of rosin and 7 parts by weight of oil or equivalent in fatty acid have these properties also.

COST OF MATERIALS USED²

Sodium hydroxid, 76 per cent, 4 pounds, at \$3.25 per 100 pounds.....	\$0.13
Cresylic acid, 95 per cent, 53 pounds, at \$0.77 per gallon.....	4.74
Linseed oil, 28 pounds, at \$2.20 per gallon.....	8.00
Soy-bean oil, 28 pounds at \$0.20 a pound.....	5.60
Rosin, 25 pounds, at \$17.50 per 280 pounds.....	1.56
Soy-bean oil, 7 pounds.....	1.40
Cost of 100 pounds of saponified cresol solution made with—	
Linseed oil, 28 per cent.....	12.87
Soy-bean oil, 28 per cent.....	10.47
Rosin, 25 per cent, soy-bean oil, 7 per cent.....	7.83

Saponified cresol solution made with linseed oil (28 per cent) costs 64.5 per cent more than that made with rosin (25 per cent) soy-bean oil (7 per cent). Saponified cresol solution made with soy-bean oil (28 per cent) costs 33.7 per cent more than that made with rosin (25 per cent), soy-bean oil (7 per cent). Saponified cresol solution made with oleic acid, fish oil (menhaden), or soy-bean oil fatty acids, would cost more than the rosin (25 per cent), soy-bean oil (7 per cent).

Bacteriological tests,³ using a modified Rideal-Walker method, were made of saponified cresol solutions containing cresol (50 per cent) and different soaps equivalent to 28 per cent linseed oil. No. 10 was made with rosin soap; No. 11, linseed-oil soap; No. 12, soy-bean-oil soap; No. 13, fish-oil soap; No. 14, rosin soap $\frac{2}{3}$, soy-bean-oil

¹ See Lewkowitsch, Chemical technology and analysis of oils, fats and waxes, ed. 5, vol. 1, p. 346, and Bureau of Standards Circular 62, p. 6.

² Oil, Paint and Drug Reporter, July 21, 1919.

³ These tests were conducted by Dr. F. W. Tilley, of the Bureau of Animal Industry. The modification consisted in the use of an unadjusted culture medium prepared as recommended by the committee of the A. P. H. A., on standard methods of examining disinfectants, in the American Journal of Public Health, July, 1918.

soap $\frac{1}{4}$; and No. 15, rosin soap $\frac{3}{4}$, fish-oil soap $\frac{1}{4}$. Just enough sodium hydroxid was used to saponify the rosin and oil. All these saponified cresol solutions were made with the same sample of cresol.

No.	Phenol co-efficient.
10	2.6
11	2.1
12	1.9
13	2.2
14	2.6
15	2.6

SUMMARY

Saponified cresol solutions have been made by using soap mixtures composed largely of rosin soap. These saponified cresol solutions have at least as great a disinfecting power as saponified cresol solutions made with linseed-oil soap, and are much cheaper. When diluted with water to a 3 per cent solution the saponified cresol solutions remain clear for varying periods, depending upon the amount of rosin soap present.

Clouding in cresol-rosin-soap solutions is due to precipitation of rosin.

Saponified cresol solutions containing soaps made from several different vegetable oils and fish oil did not vary greatly in disinfecting power.

Saponified cresol solutions containing rosin soap appear to have a somewhat higher disinfecting power than those containing only vegetable oil or fish oil.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 856

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

September 3, 1920

CURRANT-GRAPE GROWING: A PROMISING NEW INDUSTRY.

By GEORGE C. HUSMANN,

*Pomologist in Charge of Viticultural Investigations, Office of Horticultural and
Pomological Investigations.*

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Currant grapes successfully grown in this country	7		

HISTORICAL INTRODUCTION.

Very few vines of the "Corinth grapes," from which the dried currants of commerce are made, have been grown in this country, and these in California only. Many people doubtless suppose that the fruit, which is sold as dried currants and extensively used in cakes, puddings, and the like, is grown on currant bushes.¹ Botanically the varieties of currant grapes belong to *Vitis vinifera*. According to Eisen, they are referred to by Pliny as grown in Greece in 75 A. D., no further historical record of them appearing for nearly a thousand years.

During the eleventh century, in the old herbals and in the literature of the fourteenth, fifteenth, and sixteenth centuries, references to them occur as "reysyns de corauntz," "Corauntz," "Corent," "reysonys of Corawnce," "raysns of Coren," and "currans."

¹ *Ribes* sp.

The name "currant" has developed by gradual evolution from the name Corinth, the port whence the early supplies of this fruit reached western Europe. It is quite likely that the name "currant" was applied to the genus *Ribes* because of the resemblance its racemes of fruit bear to clusters of the "grape of Corinth."

Currant grapes are most extensively grown about Morea, the ancient Peloponnesus of Greece, and on the islands belonging to that country, including Cephalonia, Zante, and other adjacent islands. Of late years currant grapes have also been grown to some extent in Australia.

IMPORTANCE OF THE CURRANT INDUSTRY IN GREECE.

The devastation of the vineyards of France by the root louse¹ caused in that country a heavy demand, at high prices, for dried currant grapes to be used in the manufacture of wine and brandy. This resulted in the planting of such large acreages in Greece that in some regions the growing of these grapes became the sole industry.

The reestablishing of the French vineyards on phylloxera-resistant grape stocks introduced from the United States of America and the fact that France in 1883-84 imposed import taxes on dried currants practically excluded the Greek product from that country. This resulted in a crisis in the currant industry of Greece, as the production greatly exceeded the demand.

The "parakratisis," or "retention," act was passed by the Greek Parliament in 1895 for the purpose of maintaining prices and controlling the yearly output and to prevent as far as possible the overstocking of the markets. By its provisions every shipper of currants was obliged to deliver to the customhouse, together with his declaration of export, a receipt which showed that he had deposited in one of the Greek Government warehouses a quantity of currants equal, for example, to 15 per cent of those he desired to export. The exporter put on the bill which he forwarded to the purchaser a statement of the quantity ordered and its price, plus the price of the percentage of the whole order which he had deposited in the Government warehouse. Therefore, the foreign purchaser when buying 100 tons of currants paid the shipper for 115 tons and virtually made, through the exporter, a present of 15 tons to the Greek Government. The retention requirement was not always 15 per cent, but a figure decided upon yearly by a committee of officials from the different centers of currant production. The fruit thus donated by foreign buyers was sold by the Government to local distilleries and wine makers, with the proviso that it must not be exported as currants.

While the grower usually sold all his fruit direct to the shipper, he often preferred to deliver his inferior grades to the retention

¹ *Phylloxera vastatrix*.

warehouse, for which he received a receipt, which in Greece was negotiable and brought nearly as much as the market value of the currants.

The retained currants enabled the Government of Greece to promote the making of wines and brandies. With the money received for such currants a bank was established in 1899, called "The Currant Bank," with a capital of 3,500,000 drachmas (about \$675,000). This bank lent money on easy terms to the growers of currant grapes on the security of their crop and assisted them in other ways.

The "parakrasis" act in this way directly levies a tax upon the foreign consumer and utilizes the surplus crop; but such a law will be of avail only so long as Greece has a monopoly in currants.

About 150,000 acres are devoted to currant-grape growing in Greece, which area in a favorable season produces from 300,000,000 to 340,000,000 pounds of currants.

IMPORTS OF CURRENANTS INTO THE UNITED STATES.

The imports of currants into the United States from 1906 to 1918, inclusive, and their value are shown in Table I.

TABLE I.—*Quantity and value of currants imported into the United States for the 13-year period from 1906 to 1918, inclusive.*

Year	Pounds.	Value.		Year	Pounds.	Value.	
		Total.	Per pound. ¹			Total.	Per pound. ¹
1906.....	37,078,311	\$1,119,146	\$0.030	1913.....	20,843,735	\$1,306,410	\$0.042
1907.....	38,392,779	1,746,941	.046	1914.....	32,033,177	1,233,228	.040
1908.....	38,652,656	1,592,018	.041	1915.....	30,350,527	1,209,273	.039
1909.....	37,482,111	1,185,106	.036	1916.....	25,373,029	1,382,839	.054
1910.....	33,326,030	1,190,020	.036	1917.....	10,476,534	1,056,525	.100
1911.....	33,439,565	1,486,263	.044	1918.....	5,168,070	561,904	.109
1912.....	33,151,396	1,561,350	.047				

¹ The part of the cents shown is the nearest decimal fraction.

From Table I it appears that the United States in the decade previous to the war annually imported nearly 34,000,000 pounds of dried currants, these at an average of 4 cents per pound, costing about \$1,360,000. In 1917 the imports were 10,476,534 pounds, costing slightly more than 10 cents per pound, or \$1,056.525; but in 1918, because no more were to be had, only 5,168,070 pounds were imported, costing almost 11 cents per pound, or \$561,904.

EXPLORER'S NOTES ON CURRENANT GRAPES.

The following extract from a letter dated March 6, 1901, of David Fairchild, Agricultural Explorer for the United States Department of Agriculture, transmitted with an introduction of Panariti cuttings from Greece, is of interest in this connection:

It is the custom in Greece to plant very long cuttings [see Pl. I, fig. 2] in the rocky soil, digging down even into the bedrock, upon which the base of the cutting is allowed to rest. In Greece the vines are about 5 feet apart each way and are trained wholly without a wire or other trellis. [See Pl. I, figs. 1 and 2.] The claim is made that the fruit is so delicate, being, as is well known, an essentially seedless grape, that it requires the dense shade made by the foliage of the low sprawling canes which spring from the low-cut upright main trunk of the plant. As the clusters mature [Pl. I, fig. 4] these sprawling canes are lifted from the ground and supported on short stakes to prevent the grapes from actually lying on the ground.¹ After the petals have dropped from the flowers—i. e., when the fruit is well “set”—the vines are ringed or girdled. This girdling is done on the main trunk of the vine, a thin quarter-inch wide ring of bark being removed [Pl. I, fig. 3]. This ringing is said to be essential to the production of a large berry. It is the belief that the berries from vines not ringed are richer in sugar, not so filled with juices, and keep better than those from ringed vines [Pl. I, fig. 3]. The climate and soil in which the corinth will thrive are various. The requisites are a long summer with good insulation and a not too high temperature, 95° F. being looked on as a very high temperature in the regions where these plants are cultivated. It is a popular belief that the corinth degenerates rapidly on being introduced into foreign countries and that it even becomes a seed-bearing grape. I can not find that this belief is supported by sufficient evidence. Samples of corinths grown in Australia show that at least the plant does not produce seed there and does produce a utilizable product, which, however, is inferior in size and flavor to good Greece-grown specimens.²

CURRENT-GRAPE VARIETIES.

In Greece, where the great bulk of the currants of the world are produced, commercial crop differences are not distinguished by varieties. However, three distinct colors, white, rose, and dark, therefore three varieties, are represented.

The Black Corinth variety (synonyms, *Zante currant*, *Passerina nera*, *Corinthe noir*, *Corinthe sans pipins*, *Corinthe violet*, *Corinthien*, *Corinto nero*, *Corinthe rosso*) was among the earliest grape introductions into California. Vine very vigorous. Bunches below medium in size, compact and cylindrical with well-marked shoulders, often winged. The berries are very small, not over three-sixteenths of an inch in diameter, reddish black, round, usually seedless.

The White Corinth variety (Pl. II; synonyms, *Corinthe blanc*, *Corinto blanco*, *Corinto bianco*, *Weisse Corinthe*, *Korinthe Kleine Weisse*, *Passeretta bianca*, *Passerina bianca*, *Passera*, *Coree blanc*, *Corinthari*, *Corinthe Apro Szemufehér*), is not quite so vigorous as the Black Corinth and has leaves lighter in color, otherwise resembling it very much. Clusters larger, more conical, and more compact; berries round, white, larger, and not of as good quality; neither do they make as good a dried product as the Black Corinth.

¹ This would appear to be essentially the Chantres system of training, practiced extensively in France, especially with varieties producing the Sauterne wines.

² See U. S. Dept. Agr., Bur. Plant Indus. Bul. 66, p. 84.



FIG. 1.—GRECIAN GRAPE GATHERERS.



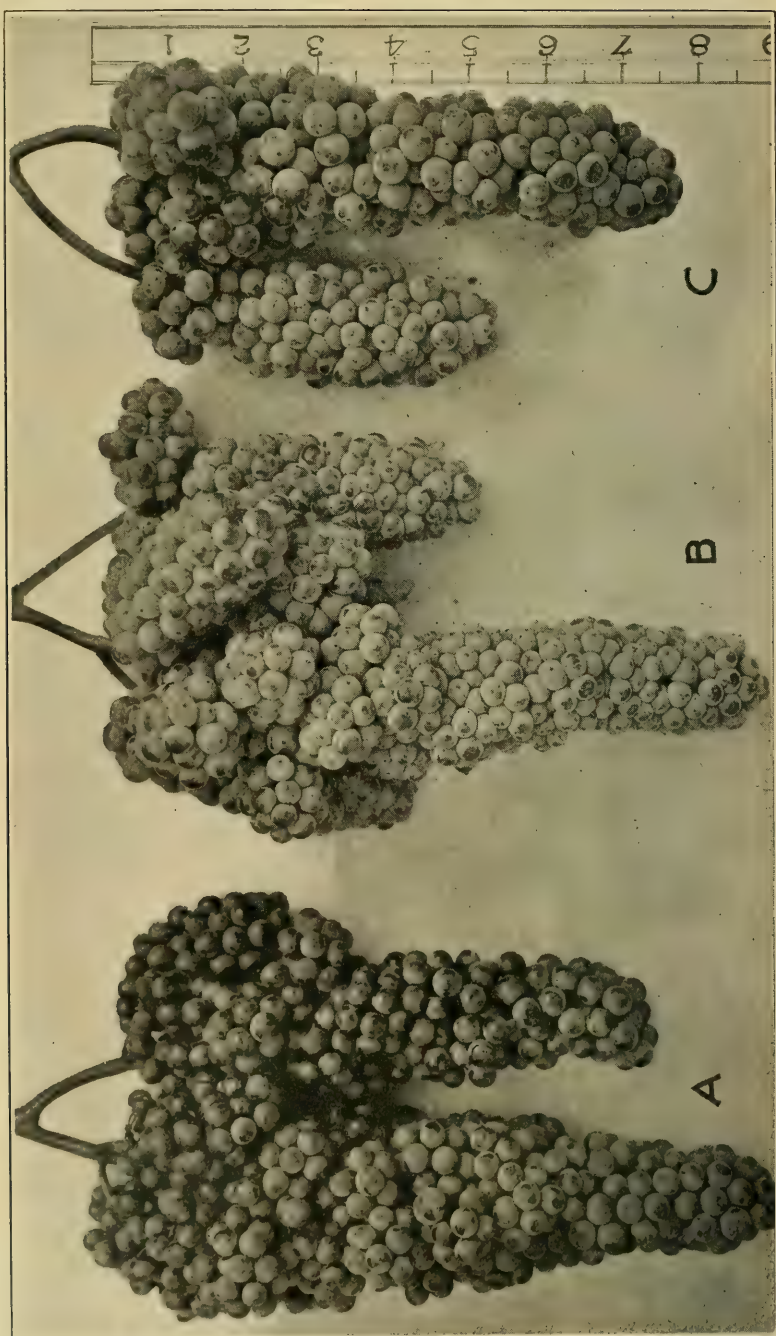
FIG. 2.—A GRECIAN VINE DRESSER.



FIG. 3.—A PRUNED VINE,
PANARITI, GREECE.



FIG. 4.—THE CHANTRES SYSTEM OF TRAINING.



A COMPARISON OF CURRANT-GRAPE CLUSTERS: A, PANARITI; B, WHITE CORINTH; C, RED CORINTH.

No trouble is experienced in making this variety bear good annual crops if accorded the same treatment that is given the Sultanina or Thompson Seedless. This probably accounts for its being grown in other than the currant-growing countries, while there is little or no such evidence with respect to the other varieties.

The vine and fruit of the Red Corinth variety (Pl. II, C; synonyms, *Corinthe rose*, *Corinthe rouge*, *Coristano rouge*) are very similar to those of the Black Corinth; the fruit, however, is lighter and rosier in color.

There appears to be no particular difficulty in successfully fruiting the white and rose-colored varieties, whereas no one in this country has been able to grow paying crops of the dark-colored grapes, which are of far superior quality either fresh or dried. This is no doubt largely due to the introduction of very poor strains, all of those that have come under the observation of the writer being inferior and worthless.

INTRODUCTION OF PANARITI CUTTINGS.¹

An introduction of Panariti cuttings (S. P. I. No. 6429) made by the United States Department of Agriculture through David Fairchild, its agricultural explorer, reached Washington, D. C., on May 9, 1901. Mr. Fairchild stated that this was "the variety of grapes producing the currants, or corinths, of commerce. These cuttings were purchased in the village of Panariti, which lies among the mountains back of Xyloncastron. The village is noted for producing some of the finest corinths in Greece." In Greece crop differences are not distinguished by varietal names, but by the name of the region in which they are produced; thus Panariti grapes are those grown in the vicinity of the village of Panariti.

The above-mentioned Panariti cuttings arrived in Washington on the very day the writer entered on his viticultural activities with the Department of Agriculture, and constituted the first lot of grape material entrusted to his care. They consisted of a medley of old and young wood of miscellaneous strength and lengths, which arrived in a somewhat dry condition. The 1-year-old wood was made into cuttings, and some of these cuttings were distributed among grape growers in California, Arizona, and southern Nevada. This dis-

¹ It may be of interest to state that some Panariti cuttings were used in an experiment to determine how long they could be immersed in hot water at different degrees of temperature without killing them, and yet kill any phylloxera or root lice that might be on them. Some of these immersed cuttings were afterward planted in the nursery in the usual manner and others made into single-eye cuttings, placed in sand in the greenhouse, and given bottom heat. The results showed that those immersed for 10 minutes in water brought to 127° F. (53° C.) were put into better condition than those immersed only 5 minutes at the same temperature. By immersing them 5 minutes at 133° F. (56° C.) the best results were obtained, whereas at 140° F. (60° C.) an immersion of only 5 minutes was not only injurious but largely fatal to the cuttings.

tribution accounts for the occasional older vines of the variety found in California.

Repeated unsuccessful attempts have been made to grow currant grapes in this country.

Vines of the Zante or Corinth currant were imported from France as early as 1854 by the Patent Office and distributed principally in the Middle and Western States. As the root louse¹ of the grapevine is an insect which is indigenous in the States east of the Rocky Mountains and as the currant grapes, like all varieties of the *Vinifera* species when they are not grafted on resistant stocks, can not resist the attack of this pest, they were probably soon killed by it.

On September 27, 1861, Col. Agostin Haraszthy, of Sonoma, Calif., imported the White and Red Corinth varieties from the Crimea.

Small plantings of currant grapes are found in different parts of California, and while a few growers have succeeded in getting fair crops of the White Corinth, no one appears to have been able to fruit successfully the superior dark-colored variety from which the currants of commerce are produced.

DESCRIPTION OF THE PANARITI GRAPE.

Because of the important part it is possible that the Panariti variety may have in the viticulture of this country the following rather detailed description of it is given:

Vine a vigorous, dense, slightly spreading grower. Young wood medium slender, round; internodes medium, long, thin; nodes slightly enlarged; buds prominent, pointed, starting early; pith large, discontinuous at diaphragm; tendrils intermittent, forked; canes light brown, striped, smooth; growing tips reddish and hairy. Leaf medium size, oblong, cordate, five lobed, margin serrate; petiolar sinuses deep, narrow, usually overlapping; upper leaf surface dark green with light-colored veins; lower surface lighter green, slightly pubescent; petiole medium slender, slightly enlarged at base.

Blossom entire, small, opens early, stamens upright, longer than pistil. Blooming period medium, blossoms abundant.

Cluster on ringed vines medium compact, cylindrical, medium length, narrow, prominently shouldered, often winged. Berries small, usually less than one-fourth of an inch in diameter, adhering well, globose, color grizzly to black, with light-colored bloom, surface smooth; skin thin, tender; flesh pearly white, soft, juicy, seedless. Flavor rich, characteristic, very high in sugar, from 28.5° to 32.2° Balling scale, and relatively high, from 0.6600 to 0.8725, in acid as tartaric (grams per 100 c. c.). Excellent in quality, both as a fresh fruit and dried. Ripens very early, from July 15 to August 15. (Pl. III.) Usually produces a very light second crop of small, round, straggling clusters of seeded berries, much larger but in quality inferior to those of the first crop.

Plate II, showing average clusters of the specially introduced Black Corinth variety from Panariti, Greece, and a cluster each of Red Corinth and White Corinth grapes, will serve better to bring

¹ *Phylloxera vastatrix*.

out the general difference between them. In such comparison, however, the description of the Panariti variety should be considered instead of that given of the Black Corinth.

CURRANT GRAPES SUCCESSFULLY GROWN IN THIS COUNTRY.

The viticultural investigations of the United States Department of Agriculture have demonstrated that the choicest varieties of these currant grapes, which formerly it was believed could not be made to bear sufficiently, can be made to produce regular and good crops. This paves the way for the establishment of another very important and extensive grape industry in this country.

An exceedingly important feature is that the currant grapes are among the very earliest to ripen; in fact, they ripen so early that they can be dried and put away before the earliest rains occur in districts where other raisin varieties are too late in ripening. In the present raisin sections of this country currants can be grown as an advance crop and cured and stored by the time other raisin grapes ripen, so that the same labor employed in harvesting and curing currant grapes can harvest and cure the other raisins after having accomplished that work.

Though exceptional difficulties were encountered in growing the choicer strains, the knotty parts of this problem have been solved. Two cardinal points must be observed in order to grow them successfully: They should be grafted on phylloxera-resistant stocks congenial to them and suited to the soil and other conditions in which they are grown, and the vines need to be thoroughly ringed at the proper time. (See Pls. IV and V.)

The experiments made by the United States Department of Agriculture at the Fresno Experiment Vineyard indicate that when vines of the currant grape are planted at distances the equivalent of 8 by 8 feet apart, as Vinifera vineyards usually are, an acre of good vineyard in this country will yield from 6 to 15 tons (an average of $10\frac{1}{2}$ tons) of grapes, or, conservatively, from 2 to 5 tons of cured currants. From this it will be seen that 3,400 to 8,500 acres would be necessary in order to produce the 34,000,000 pounds which normally are annually imported, and no doubt the consumption could be very much increased beyond its present limits.

CONDITIONS SUITED TO CURRANT-GRAPE CULTURE.

All of the good vineyard soils in the Vinifera regions of the United States are probably suitable for currant-grape growing. The congeniality tests of Panariti grapes on phylloxera-resistant stocks, of which mention is made later, have demonstrated that this variety will do well on a sufficient number of stocks to permit a

selection of such as are well suited to the principal types of vineyard soil.

All the districts in California in which grapes for various purposes are now grown appear to have suitable conditions for the growing of currant grapes. The fruit of the same *Vinifera* varieties, when grown in some of the bay counties of California, is of finer quality than when grown in the San Joaquin Valley, and it is reasonable to suppose that the same may be true of the Panariti variety.

It is, of course, a great advantage in growing grapes for drying purposes to be in a district which permits sun drying. Protection against the dew at night will probably be necessary in some of the coast districts, but it is preferable that the currant grapes be shaded most of the time while drying and the same shelter can be made to answer both purposes.

ANALYSIS OF THE SOIL OF THE FRESNO EXPERIMENT VINEYARD.

Because most of the investigations of the currant grapes have been made at the Fresno Experiment Vineyard of the United States Department of Agriculture, 3 miles east of Fresno, Calif., the mechanical analysis of the soil of that locality, made by the Bureau of Soils of the United States Department of Agriculture, will be of interest. (Table II.)

TABLE II.—*Analysis of the soil of the Fresno Experiment Vineyard, near Fresno, Calif.*

Description and depth of soil.	Mechanical constituents (per cent).							
	Coarse gravel.	Fine gravel (2 to 1 mm.).	Coarse sand (1 to 0.5 mm.).	Medium sand (0.5 to 0.25 mm.).	Fine sand (0.25 to 0.1 mm.).	Very fine sand (0.1 to 0.05 mm.).	Silt (0.05 to 0.005 mm.).	Clay (0.005 mm. and smaller).
Brown sandy loam								
0 to 12 inches	0.58	1.2	9.8	6.7	18.4	12.0	32.3	19.7
12 to 24 inches	.71	.9	9.1	6.9	17.8	12.3	32.5	21.4
Sandy loam								
0 to 12 inches	.51	.6	8.3	7.8	19.9	12.9	27.1	23.5
12 to 24 inches	.35	.9	8.8	6.0	13.7	13.1	36.3	21.4
24 to 36 inches	.11	1.2	14.2	8.6	22.4	15.7	26.5	11.1

This type of soil about 75,000 acres near Fresno, 6,000 acres near Hanford, and about 265,000 acres in the Sacramento Valley have been mapped by the Bureau of Soils. For further descriptions of these soils, see Bureau of Plant Industry Bulletin 172, entitled "Grape Investigations in the *Vinifera* Regions of the United States with Reference to Resistant Stocks, Direct Producers, and *Vinifera*," and the surveys of the Bureau of Soils.



CLUSTER OF PANARITI GRAPES.

The lines on the left margin indicate inches.



FIG. 1.—PANARITI (RINGED VINE) YIELDED 33 POUNDS OF GRAPES.



FIG. 2.—PANARITI (NOT RINGED) YIELDED 6½ POUNDS OF GRAPES.

COMPARISON OF TWO VINES OF THE PANARITI VARIETY.

These two vines, grafted on the same stock (Rupestris St. George), growing side by side, of the same age, and comparable in every way, received the same attention and care except that a ring of bark one-fourth of an inch wide was removed at blossoming time from the trunk (see arrow) of the vine shown in figure 1. Both vines were photographed at fruit-ripening time.



FIG. 1.—TRUNK OF VINE, SHOWING THE RINGING DONE ON MAY 23, 1917, WHEN THE VINE WAS IN BLOOM.



FIG. 2.—THE SAME VINE, SHOWING THE RINGING ON ITS TRUNK HEALED OVER, JULY 15, 1917, WHEN THE FRUIT WAS RIPE.

TWO VIEWS OF A PANARITI GRAPE VINE GRAFTED ON ARAMON × RUPESTRIS GANZIN NO. 1.



FIG. 1.—CROSS PLOWING A VINEYARD TRAINED TO STAKES.



FIG. 2.—A VINEYARD TRAINED TO STAKES READY FOR PLOWING.



FIG. 3.—A TRELLISED VINEYARD AFTER PLOWING.

PREPARATION OF THE SOIL, PLANTING, AND CULTURE OF CURRANT VINEYARDS.

When virgin soil is to be used, and even when the land has previously been in vineyard, it can be put in better shape if a crop of grain is grown on it the season before planting. After being plowed and subsoiled, the land should be thoroughly harrowed and the clods crushed with a drag or roller.

Since the currant grapes are true *Viniferas*, the usual practices in growing and caring for such grapes will apply to them. Some plant the vines 8 feet apart each way, others plant them 6 by 10, 9 by 9, 8 by 10, or even wider distances apart when stakes are used as supports. When trellises are used the vines are planted 12 by 6, 14 by 6, 14 by 8, or 16 by 8 feet apart. In the first plowing the soil is usually thrown away from the vines, and in the second plowing it is thrown up against them again. (Pl. VI, fig. 3.) When stakes only are used as supports the grower can plow and cultivate lengthwise and crosswise. (See Pl. VI, figs. 1 and 2.) In doing this the vineyards are plowed twice annually. The soil is kept level and more evenly worked up. If the first plowing is north and south, for example, the second should be east and west, while the next year the opposite course is pursued. Furthermore, the cultivation or harrowing given after each plowing is at right angles to the plowing and not parallel with it. (See Pl. VI, fig. 1.) In the *Vinifera* regions all plowing and culture is abandoned after the spring rains are over. Where irrigation is not necessary it should not be practiced.

PRUNING AND TRAINING THE VINES.

In our experiments with currant grapes a number of pruning and training methods have been tried. With simple stakes as a support, the following, among others, have been used: Spur, stools, or short pruning; long, or cane pruning (fig. 1); canes with laterals; and long canes bent over and tied as a circle (fig. 2). With trellises as a support, the following systems have been tested: Two-cane renewal, 4-cane renewal, fan system, high renewal, low renewal, Munson system, etc. The best all-around results with these grapes have been obtained by training them according to the long or cane pruning system. (Fig. 1.) For explanations and illustrations of the different pruning systems, see *Farmers' Bulletin 471*, entitled "Grape Propagation, Pruning, and Training." For Panariti vines in fruit trained in this way, see Plate IV, figures 1 and 2. The cheaper training systems, permitting cross culture of the vineyards, give good results with Panariti grapes, but since annual ringing is necessary in order to obtain full crops and since stakes would interfere

with the work of ringing, the vines need to be trained to carry themselves without support at the age of fruiting. If stool pruning to fairly high heads is not practicable and no better way is found, the same purpose may be accomplished by pruning so as to leave the canes long enough to permit bending and tying to form a self-supporting circle, as shown in figure 2.

Experiments are now being made to determine the methods of pruning, training, and culture necessary for the best results. It would be an easy matter, of course, to select a trellis system of training that would adapt itself to the growing of the currant-

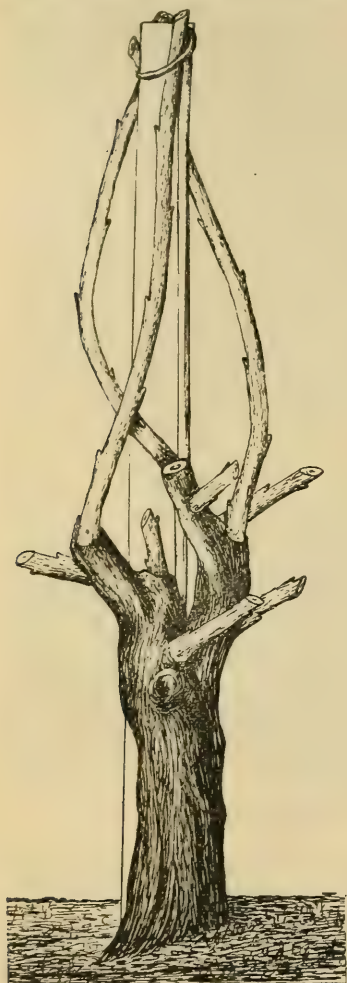


FIG. 1.—A grapevine pruned to canes.

grape varieties if it should be determined that it is best to prune them long and train them to a trellis, as is recommended in California Experiment Station Bulletin 298, entitled "The Seedless Raisin Grapes."

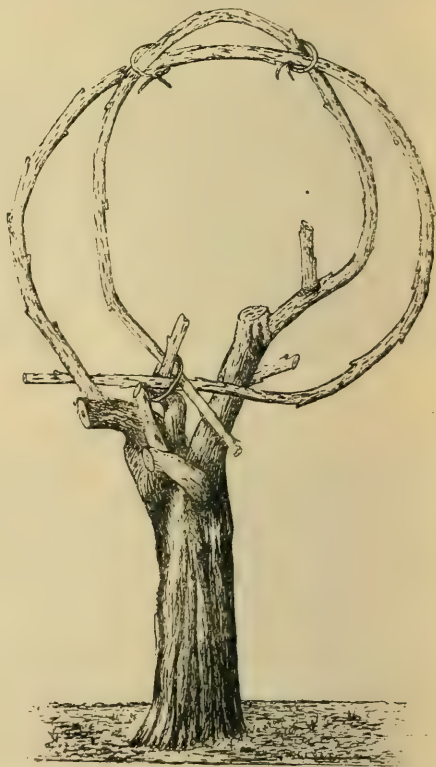


FIG. 2.—A grapevine pruned to long canes, the canes afterwards being bent in a circle as a support.

RINGING THE VINES.

It has been found that in order to make the blooms set and secure full yearly crops of grapes the vines must be ringed every year.

This ringing consists of making two parallel incisions through the bark and cambium layer around either the trunk, the arms, or the canes of the vines and completely taking out the bark and cambium layer between the two parallel incisions. (Pl. V, fig. 1.) This does not interfere with the upward flow of the sap through the outer ring of undisturbed wood, but where the ringing occurs checks the returning flow while the ringed place is healing. (Pl. V, fig. 2.) The effects of ringing are a full setting of fruit and much larger berries and clusters. (Pl. IV, figs. 1 and 2.) The ringing is done either with a large-bladed pocketknife or with special tools made for the purpose (fig. 3).

In ringing several factors need special consideration. The time the ringing is done is a most important matter and is related to the blooming period. If done either too early or too late, the desired results will not be obtained. It is best to do the ringing when the clusters are partially in bloom or in the middle of the blooming period. The blooming period being of relatively short duration (usually not more than 10 days), when ringing on an extensive scale it is advisable to start just as the first flowers open and continue ringing throughout the blooming period. The effects on fruit setting are noticeable with vines ringed after they stop blooming.

The depth of the incisions is also very important. They should be made entirely through the cambium layer, and the matter between the two incisions should be immediately and completely removed. The results obtained will depend on the thoroughness of this part of the operation.

The width between the two parallel incisions is also an important matter. The distance between the incisions should be no wider than is absolutely necessary to allow a narrow circle of the bark and cambium to be removed. On the arms and canes of vines a circle one-eighth of an inch wide is sufficient; for large arms and trunks of vines a circle one-fourth of an inch wide is necessary. If good judgment is used in doing this work the circle removed on the vines ringed while in bloom should be completely healed over in six to eight weeks, or by the time the grapes are ripe.

Another important factor is the part of the vine to ring. The effects on the vine are manifest, of course, only beyond the place of

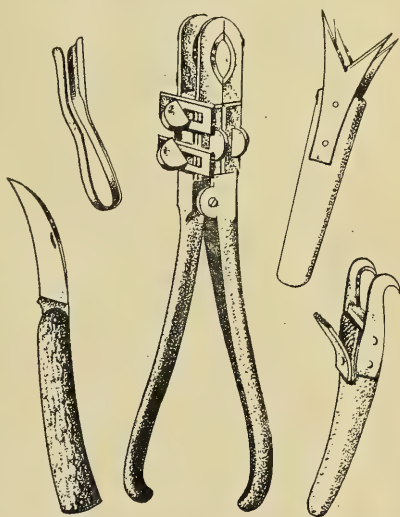


FIG. 3.—Some tools used in ringing vines.

ringing. Hence, the entire vine is affected by one ringing of the trunk, but when either arms or canes are chosen all of them must be ringed, in order that the entire vine may be affected.

In the experiments conducted at the Fresno Experiment Vineyard, 12-year-old ringed Panariti grafts on 10 different resistant stocks trained to stakes (vines 8 by 8 feet apart, or 680 to the acre) during 1917 and 1918 gave average annual yields per acre ranging from about 5.8 tons (Pl. IV, fig. 1) on the poorest stock to 10.35 tons on the best stock, the average on all the stocks being nearly $7\frac{1}{2}$ tons. The check vines with like treatment and care averaged only $2\frac{1}{3}$ tons to the acre (Pl. IV, fig. 2). Ringed 5-year-old Panariti grafts on 18 different resistant stocks, with trellis training (vines 8 by 8 feet apart, or 680 to the acre) during 1917 and 1918 averaged annually over 5 tons to the acre, while the check vines averaged only 1.9 tons to the acre.¹

CONGENIALITY OF THE PANARITI VARIETY TO PHYLLOXERA-RESISTANT STOCKS.

In the belief that an important new grape industry can be developed from the dried fruit of the Panariti grape, and that it is destined to play an important rôle in *Vinifera* viticulture, this variety was one of those selected for extensive tests of the congeniality of *Vinifera* grape varieties to the important phylloxera-resistant stocks at the Fresno Experiment Vineyard in California.

In a 10-year test of the Panariti variety grown on various resistant stocks, a sufficient number of varieties of these stocks have been found from which to select those which are adapted to any of the types of grape soil, as well as to other conditions which are congenial to the currant-grape varieties and on which they show a tendency to good fruiting.

The data given in Table III show the relative behavior of Panariti vines growing on 10 different phylloxera-resistant stocks in the Fresno Experiment Vineyard. Ten vines each of the Panariti grape grafted on the Lenoir, Rupestris St. George, Riparia Gloire, Salt Creek, and Dog Ridge were included in the tests. Of each group of 10 vines, 2 were check vines, 4 were vines with canes ringed, and 4 were vines with trunks ringed. Five vines each of Panariti variety grafted on the Adobe Giant, Aramon $\times$ Rupestris Ganzin No. 1, Mourvedre $\times$ Rupestris No. 1202, Riparia $\times$ Rupestris No. 3309, and Solonis $\times$ Riparia No. 1616 were also included in the tests. Of each group of five vines, one was a check vine, two were vines

¹ For further information on the adaptability of resistant stocks to soils and other conditions see Bureau of Plant Industry Bulletin 172, entitled "Grape Investigations in the *Vinifera* Regions of the United States with Reference to Resistant Stocks, Direct Producers, and *Viniferas*," and Department of Agriculture Bulletin 209, entitled "Testing Grape Varieties in the *Vinifera* Regions of the United States."

with canes ringed, and two were vines with trunks ringed. All these vines were trained to stakes.

TABLE III.—*Relative behavior of check vines and ringed vines of the Panariti variety of currant grapes grafted on 10 varieties of phylloxera-resistant stocks trained to stakes at the Fresno Experiment Vineyard of the Department of Agriculture in California for a period of 10 years, together with fruiting results in 1917 and 1918.*

Name of the variety and of the stock upon which it was grown.	Congeniality.	Range of dates in the 10-year period.		
		Growth starting.	Blooming.	Fruit ripening.
1	2	3	4	5
Panariti variety:				
Adobe giant.....	89	Mar. 2 to Mar. 28....	May 2 to May 25....	July 20 to Sept. 2.
Aramon X Rupestris Ganzin No. 1.....	96	Mar. 1 to Apr. 1.....	May 6 to May 28....	July 15 to Sept. 15.
Dog Ridge.....	93	Mar. 6 to Mar. 26....	May 1 to May 22....	July 15 to Sept. 10.
Lenoir.....	86	Mar. 2 to Mar. 27....	May 1 to May 20....	July 15 to Sept. 5.
Mourvedre X Rupestris No. 1202.....	92	Mar. 4 to Apr. 1.....	May 5 to May 20....	July 15 to Sept. 12.
Riparia Gloire.....	89	Mar. 4 to Mar. 26....	May 2 to May 20....	July 22 to Sept. 10.
Riparia X Rupestris No. 3309.....	95	Mar. 4 to Mar. 27....	do.....	July 15 to Sept. 16.
Rupestris St. George.....	95	Mar. 5 to Mar. 27....	May 2 to May 23....	July 15 to Sept. 14.
Salt Creek.....	85	Mar. 1 to Mar. 26....	May 1 to May 20....	July 15 to Sept. 15.
Solonis X Riparia No. 1616.....	92	Mar. 5 to Mar. 28....	May 2 to May 20....	July 15 to Sept. 16.

Name of the variety and of the stock upon which it was grown.	Yield of fruit (pounds).				Sugar content (Balling scale).		Acid as tartaric (grams per 100 c. c.).	
	In 1917.		In 1918.		In 1917. In 1918.		In 1917. In 1918.	
	Check vines.	Ringed vines.	Check vines.	Ringed vines.				
1	6	7	8	9	10	11	12	13
Panariti variety:								
Adobe Giant.....	7.5	27.25	7.5	30.5	30.5	27	0.9675	0.8770
Aramon X Rupestris Ganzin No. 1.....	21	36.25	11	20.25	28	26	.7650	.8255
Dog Ridge.....	3	12	3	22.5	26.5	28	.8300	.8250
Lenoir.....	1.5	13.25	2	10.25	28	26	.6450	.7500
Mourvedre X Rupestris No. 1202.....	8	19.5	1.5	13.5	23.5	28	.8700	.7575
Riparia Gloire.....	5	19.5	2	7.75	23.5	30	.8850	.9450
Riparia X Rupestris No. 3309.....	17	30.25	20	28.5	28.5	26	.8650	.8250
Rupestris St. George.....	6.5	15.5	2	20.5	28.5	26	.7800	.8550
Salt Creek.....	8	19.25	1.5	15.5	28	26	.7800	.8175
Solonis X Riparia No. 1616.....	24.5	26.25	19	16	29	26	.6900	.8325
Average.....	10.2	21	6.95	18.525	27.4	26.9	.80775	.8310

The significance of the data in the various columns of Table III is made clear by the following explanation:

Column 1 shows the name of the variety and of the stocks upon which it was grafted.

Column 2 shows the congeniality existing between the resistant stock and the variety grown upon it, expressed in the form of a percentage rating on a scale in which the growth of the variety when not grafted but growing as an entire plant on its own roots, under conditions to which it is well adapted, is taken as the standard of excellence, 100 per cent. The congeniality percentages therefore represent the behavior of the Panariti variety when grafted on the several stocks in the Fresno Experiment Vineyard expressed in terms that permit com-

parison with its behavior when growing as an entire plant on its own roots. To illustrate, the table shows that as to congeniality the Panariti when grafted on Aramon $\times$ Rupestris Ganzin No. 1 was rated at 96, when on Dog Ridge at 93, and when on Salt Creek at 85. This shows that the Panariti variety, which is well adapted to the conditions in the Fresno Experiment Vineyard, when grafted on these stocks at the same time under the same conditions, with the same treatment in the same vineyard, varied in growth and behavior in comparison with the variety on its own roots in accordance with the above ratings.

Columns 3 and 4 show the earliest and the latest date of starting into growth and of blooming, respectively, on the 10 stocks during the 10 years. These data are given as a basis of comparison with other grape varieties growing in the same locality. As the vines must be ringed while they are blooming, the blossoming data also indicate the time of year when the ringing must be done.

Column 5 shows the earliest and the latest date of fruit ripening on the 10 stocks during the 10 years. This serves to show that currant grapes can be grown in advance of other raisin grapes and that they may be sun dried before the fall rains start in districts where other raisin grapes ripen too late.

Columns 6 and 7, respectively, show the yield of fruit per vine that the Panariti check vines bore in 1917 on each of the 10 stocks, compared with the yield of fruit per vine borne by ringed Panariti vines on the same stocks growing side by side, with otherwise the same care and treatment given them the same year.

Columns 8 and 9, in like manner, afford a comparison of the yields of fruit in 1918.

Columns 10 and 11 compare the sugar content (Balling scale) of the fruit of the Panariti variety on each of the 10 stocks in the years 1917 and 1918, respectively.

Columns 12 and 13 compare the acid content (grams per 100 c. c.) of the fruit of the Panariti variety on each of the 10 stocks in the years 1917 and 1918, respectively.

Table IV shows the relative behavior of two young Panariti vines (ringed), each growing on 15 additional stocks, during a 4-year period, the vines being trained to a trellis. Explanations similar to those given for the same columns in Table III apply to columns 1 to 5 in Table IV. Columns 6 and 7 show the relative quality and yield of fruit of the Panariti vines on each of the 15 different resistant stocks.

The data in Table IV relating to the behavior of young Panariti vines trained to a trellis for only two vines each on 15 resistant-stock varieties do not allow a fair comparison with data in Table III of the behavior of older vines trained to stakes, but promises of larger yields with trellis training are indicated. More elaborate tests of these and other stocks are now under way to obtain more conclusive data as to congeniality.

The results of the ringing experiments for 1919 have not been compiled as yet. It is known, however, that they corroborate and strengthen the results obtained in 1917 and 1918, and that the actual yields in 1918 were fully 10 per cent heavier than those of 1917, when the heaviest crop that up to that time had been grown was obtained.



FIG. 1.—DRYING CURRANTS ON WOODEN TRAYS.



FIG. 2.—DRYING CURRANTS ON WIRE-SCREEN TRAYS.

TABLE IV.—*Relative behavior of ringed vines of the Panariti variety of currant grapes grafted on 15 varieties of phylloxera-resistant stocks, trained on a trellis at the Fresno Experiment Vineyard of the Department of Agriculture in California, showing the fruiting results in 1918.*

Name of the variety and of the stock upon which it was grown.	Congeniality.	Range of dates in 4-year period.			Fruit borne in 1918.	
		Growth starting.	Blooming.	Fruit ripening.	Quality.	Weight per vine (pounds).
1	2	3	4	5	6	7
Panariti variety:						
Aramon × Rupestris Ganzin No. 2..	74	Mar. 12 to Mar. 30.	May 7 to May 14.	July 22 to July 25.	Very good..	17
Berlandieri × Riparia No. 420-A....	84	Mar. 12 to Mar. 26.	May 5 to May 8.	July 20 to July 22.	Excellent..	25
Clairette dore' Ganzin.....	89	Mar. 12 to Mar. 25.	May 6 to May 9.	Aug. 2 to Aug. 9.	Very good..	32.5
Constantia.....	86	Mar. 12 to Mar. 23.	May 6 to May 13.	July 25.....	do.....	12.5
Hotporup.....	65	Mar. 10 to Mar. 27.	do.....	July 22 to July 25.	Good.....	12.5
Monticola × Riparia No. 18804.....	88	Mar. 10 to Mar. 23.	May 5 to May 13.	July 19 to July 25.	Very good..	13
Monticola × Riparia No. 18808.....	74	Mar. 10 to Mar. 24.	May 6 to May 17.	July 22 to July 25.	Good.....	23
Monticola × Rupestris.....	89	do.....	do.....	July 19 to July 25.	Very good..	12.5
Riparia × Rupestris No. 3306.....	88	Mar. 12 to Mar. 28.	May 5 to May 15.	July 20 to July 25.	Excellent..	12.5
Riparia × Rupestris No. 101-14.....	74	Mar. 12 to Mar. 26.	May 6 to May 19.	July 24 to July 25.	Very good..	6
Rupestris Martin.....	76	Mar. 13 to Mar. 27.	May 5 to May 19.	Aug. 1 to Aug. 9.	do.....	13.5
Rupestris Mission.....	69	Mar. 13 to Mar. 25.	May 7 to May 19.	do.....	do.....	15.5
Rupestris × Berlandieri No. 219-A..	81	Mar. 13 to Mar. 29.	May 6 to May 17.	July 25.....	do.....	13
Solonis Robusta.....	84	Mar. 9 to Mar. 23.	May 5 to May 17.	July 18 to July 25.	do.....	7.5
Viala.....	86	Mar. 11 to Mar. 24.	May 5 to May 18.	Aug. 1 to Aug. 9.	do.....	34

HARVESTING AND CURING CURRANTS.

DRYING AS FORMERLY PRACTICED IN GREECE.

The following is quoted from the Agricultural Explorer's notes under date of March 6, 1901:

The drying of the fruit is an important process, and there is one common substratum upon which all the corinths of commerce are dried. It is a sun-baked paste of cow manure. Whether a drying floor is prepared on open spots of ground scattered through the vineyards or consists of a large number of light wooden trays to be carried by the hand, makes no difference, both must be first painted with a thick coat of the above-mentioned paste and allowed to dry in the sun. The explanation given is that the dried paste absorbs the moisture from the injured grapes and continues during the night to absorb moisture, as a coating of blotting paper would. In addition to this important office as an absorbing stratum it is claimed that the fumes of ammonia which are given off by it have the effect of giving the berries the desired dark-blue color which is demanded by the trade. Whatever may be said in favor of this method of curing, it can not fail to strike the unacquainted as an exceedingly curious and objectionable one. A visit to the drying fields does not conduce to a removal of one's objection to such a method. Some improved clean substratum ought to take the place of this old one, even though it ruin the large manufactures of manure paste.

Since the date mentioned above, the methods of drying, curing, and marketing currants in Greece have apparently become more modern and sanitary.

DRYING AS PRACTICED AT FRESNO.

In the drying experiments with currant grapes made in the Fresno Experiment Vineyard by Mr. Elmer Snyder, scientific assistant, wire-screen trays and the ordinary wooden trays were used. The wire-screen trays allow slightly more uniform drying, but this is not important enough to justify the difference in the cost of the trays. (See Pl. VII, fig. 2.) A first-class entirely satisfactory product (in every way superior to imported currants) was obtained by using wooden trays. (See Pl. VII, fig. 1.) Because these grapes ripen so very early (Tables III and IV) there is practically no danger from rain at Fresno. The sun is very hot there at that time, and as the berries are very small, thin skinned, and high in sugar content little time is required to complete the drying process. The grapes should not be picked until they are fully ripe or, in the case of the Panariti variety, until they test from 28° to 32° Balling scale, varying with the season. The fruit as picked was placed on the trays, and it was found that it needed no turning, as it was exposed to the sun only a day or never longer than two days. The trays of drying grapes were then stacked one on top of another, with wooden strips between them to separate the trays, so that there was free circulation of air through them. Empty trays or some other covering were put on the top of the stack. An average of 15 days was required for the drying grapes to remain stacked before they were sufficiently cured to be transferred to the sweat boxes.

In drying experiments made during three seasons it has been found that when the Panariti grapes were picked at 26° Balling scale it took practically 3½ pounds of fresh fruit to make 1 pound of the dried product, while when picked at 30° to 32° Balling scale it required scarcely 3 pounds of fresh fruit to make 1 pound.

DRYING PRACTICE IN DRY-WINE SECTIONS.

In the dry-wine sections of California, where the Panariti variety will, in the average seasons, ripen sufficiently early to be dried out of doors without any interference from rain, the drying will need to be somewhat modified, because the sun usually is not so hot. The grapes when placed on the trays need to be exposed a greater number of days and the trays should be covered during the night to protect them from dew. After the partially dried grapes are stacked, the further procedure with them is like that previously described.

For fuller particulars as to raisin curing, consult United States Department of Agriculture Bulletin 349, "The Raisin Industry." Copies of this can be had by sending 10 cents, the price of the bulletin, to the Superintendent of Documents, Government Printing Office, Washington, D. C.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 857

Contribution from the Bureau of Markets
GEORGE LIVINGSTON, Acting Chief



Washington, D. C.

PROFESSIONAL PAPER

June 25, 1920

A MODIFIED BOERNER SAMPLER.

By E. G. BOERNER, *In Charge, Grain Investigations*, and E. H. ROPES, *Specialist in Grain Investigations*.

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INTRODUCTION.

The device described in this bulletin was developed primarily to meet the demands of grain dealers and laboratory workers for a cheap and simple method of securing from a larger sample to be graded a smaller representative portion of grain for testing and analyses purposes. Another application of the device, which should be of special interest to the grain trade, is that a sample can be divided into two or more representative parts, so that one representative part may be used for testing and grading and the other part or parts may be turned over to the seller or the buyer of the grain, or retained for future reference. It can also be used for reducing the size of samples of seeds, flour, meal, feeds, or any other material of like kind for examination or analyses. This device should be of special interest to country grain dealers. A phantom view of the device completely assembled in operation is shown in figure 1.

The device (commonly known to the trade as the "Boerner Sampler") described in Department of Agriculture Bulletin No. 287 was developed primarily for the purpose of dividing an original sample into smaller portions, which might be analyzed without the undue loss of time incident to handling a large sample, and to make this division in such a manner that each small portion would correctly retain the original proportion of the various factors comprising the

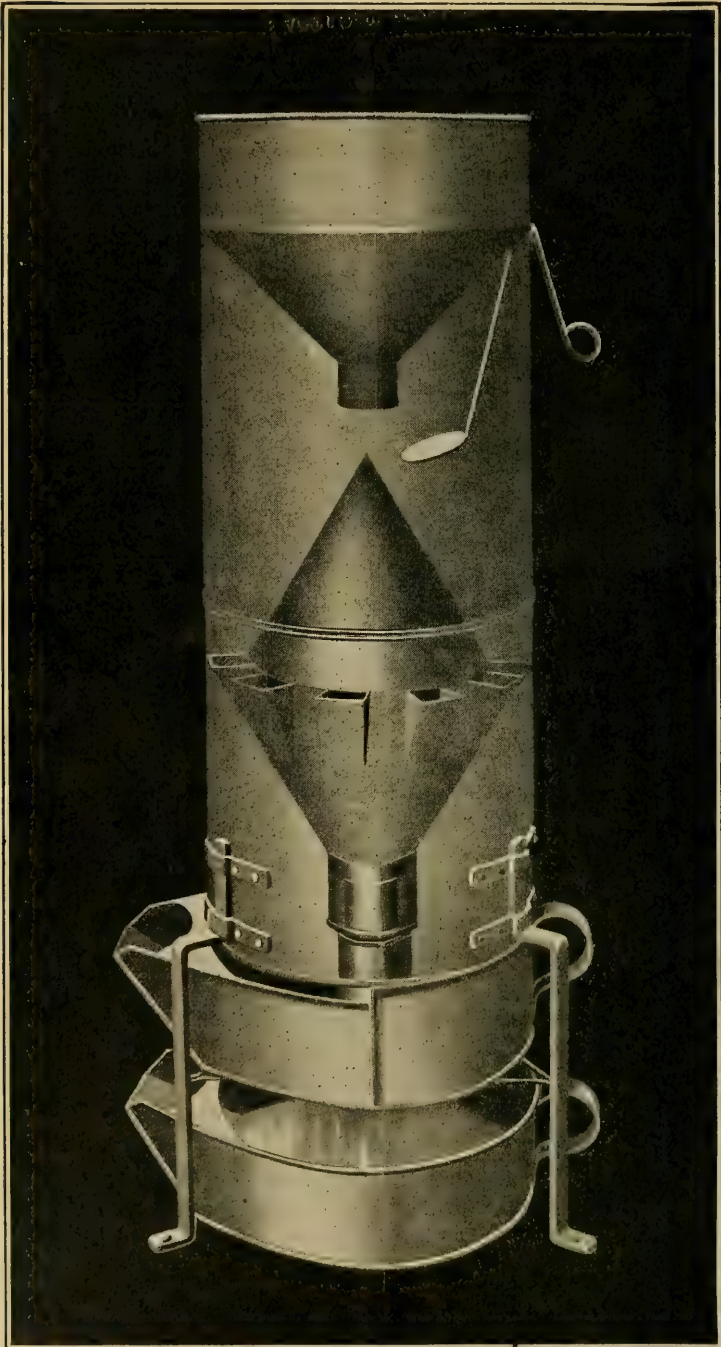


FIG. 1.—Phantom view of device. American manufacturers and users of this device are protected by a public-service patent.

original sample. The original standard design is more complicated to manufacture than the modified sampler here described, but it is so constructed that it is somewhat more convenient to work with. It is used at all offices of Federal Grain Supervision, and is recommended for grain inspection departments and others who have to do a large amount of grading or testing.

During the past few years the increased cost of material and labor has caused the cost of the original standard device to advance to such an extent that many grain dealers, especially country grain dealers, have not felt justified in purchasing it.

Following the Department of Agriculture's policy of bringing the equipment necessary for correct grading within the financial reach of all persons concerned, the original standard design for this device has been modified so as to cheapen its construction materially and bring its cost within the reach of all persons interested in grain grading.

The first essential in the accurate grading of grain is the securing of a representative sample of the lot or parcel of grain to be graded. A representative sample varies in size somewhat as the bulk of the lot to be sampled varies. For the weight per bushel test or dockage determination, the quantity of the sample to be used is fairly large, and for these tests reduction in size may not always be necessary, but in every case the amount of the sample is many times larger than can be conveniently analyzed or tested for such factors as foreign material, other grains, damaged kernels, or moisture content. In order to obtain a portion small enough for these analyses and tests it is essential that the size of the original sample be reduced.

Mere haphazard reduction of size of sample, however, leads only to confusion and disputes between the interested parties. Among haphazard methods of cutting down the size of the sample might be mentioned: Pouring out a portion of the sample; taking out a portion with a scoop or with the hand; dividing the sample with a ruler; or any other solely manual method. When a small portion is taken out of a larger sample by any of these methods it almost invariably results in removing either too great or too small a proportion of foreign matter, broken grains, damaged kernels, and admixtures of other grains; and even though this may not in some cases affect the result of certain tests, as for instance the moisture test, it may, and usually does, seriously affect the correct proportion of the admixtures in the remaining portion of the sample upon which the other tests are based, and incorrect grading is a common result.

The reduction of the size of the original sample for analysis and testing is generally necessary and the retention of the relative proportions of the admixture of various other grains, foreign substances, broken kernels, and damaged kernels, of which the original was made

up, is in such cases absolutely essential to correct grading; but without the aid of a mechanical device the retention of correct proportions with such a reduction is hardly possible.

One familiar with grain grading knows that to obtain uniform results the tests and analyses must be made on samples obtained in a uniform manner. It is surprising how slight a variation in the method of obtaining either the original sample or a portion of the sample for certain tests will cause a difference in the result; yet we find many methods in everyday use, when the country as a whole is considered.

To grade grain accurately requires not only a thorough knowledge of the grain to be graded and the grade requirements, but also accurate determinations of the grading factors, and for these determinations proper apparatus is necessary. A sample-splitting device for reducing the size of a sample for analyses and testing is considered essential for correct grain grading, and for reasons already explained the modified device described in this bulletin was designed especially for use by country grain dealers.

DESCRIPTION.

The modified sampler consists primarily of the following parts: Two cylinders partially nesting or telescoping; two pans, or containers; and three legs. The upper cylinder with its parts forms a hopper with gate; the lower cylinder contains a spreading cone, diverting ducts, and a funnel. Figure 2 shows the device completely assembled and ready for operation.

The upper cylinder is designed to slide down inside of the lower cylinder until it rests upon the partitions of the diverting ducts arranged around the base of the cone, where it is held in proper position. A funnel is set down inside of the upper cylinder so that with the cylinder it forms a hopper of ample capacity, shown in figure 3. This hopper is provided at its bottom with a gate that may be opened or closed by means of a convenient handle extending through to the outside of the cylinder. A bottom view of the hopper and gate is shown in figure 4.

The lower cylinder contains the spreading cone, and holds it so that its point is directly under the center of the opening in the bottom of the hopper in the upper cylinder. The diameter of the spreading cone at its base is less than the diameter of the cylinder, and the space between the cone and cylinder is subdivided into a given number of equal spaces by radial partitions extending from the base of the cone to the cylinder wall. The arrangement of the partitions as shown in figure 3 is such that any material passing through the device, by way of the hopper, and sliding down over the surface of the cone, is divided into as many equal streams as there are spaces between the partitions around the base of the cone. Every other

stream of material falls into one pan, while the alternate streams are diverted into the other pan, thus dividing the original material (sample) into two equal parts. The separation of the streams is accomplished by leaving the openings between the radial partitions unobstructed in every other space, and in the alternate spaces, between those left clear, providing bottoms which, with the partition as sides, form diverting ducts. The streams of material passing through the unobstructed openings fall directly into the upper pan. The streams passing through the ducts are diverted into a funnel, shown in figure 4, which collects the streams from all the ducts and discharges them as one stream (which is one-half of the original material) into the lower pan through a protected opening in the upper pan..

The upper pan, illustrated in figure 5, is designed so that it catches and holds the half of the material passing through the unobstructed openings, but permits the other half of the material, which has passed through

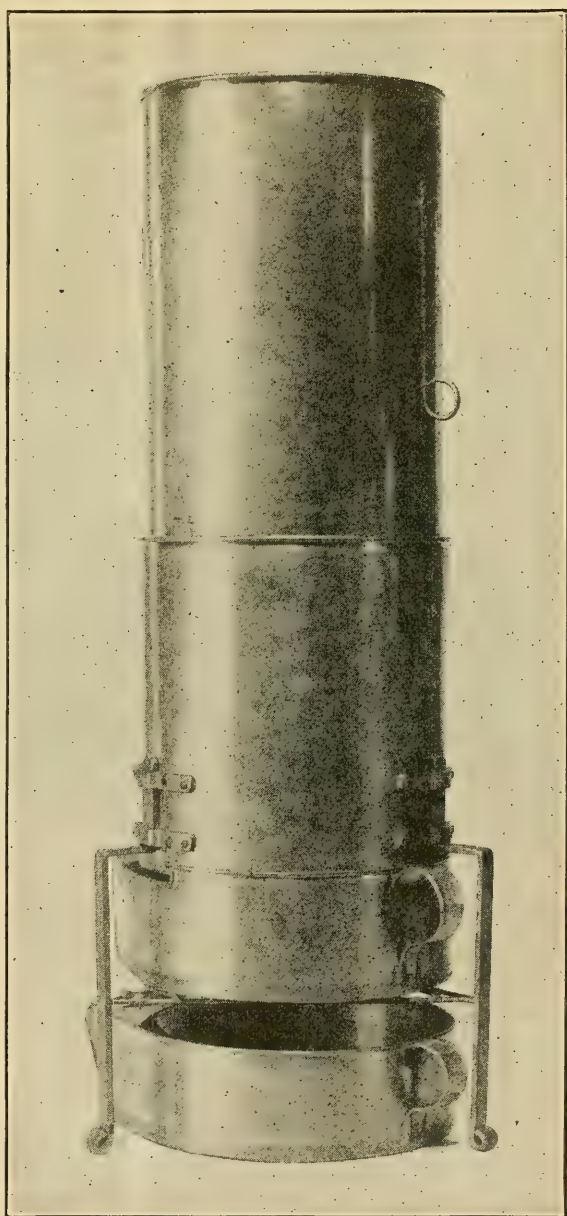


FIG. 2.—Side view of complete device.

the diverting ducts and funnel, to fall into the lower pan through a protected opening. The lower pan, also shown in figure 5, is a simple receptacle with a handle and a pouring spout.

Three detachable legs are provided to carry the lower cylinder, and on these legs are supports for the upper pan.

The device can be made of brass or block tin, but the material used must be of sufficient stiffness to resist bending or denting under working conditions.

The primary purpose of this device is to divide an original sample into smaller portions, which may be analyzed without the undue loss of time incident to handling a large sample, and to make this division in such a manner that each small portion will correctly retain the original proportion or percentage of the various factors

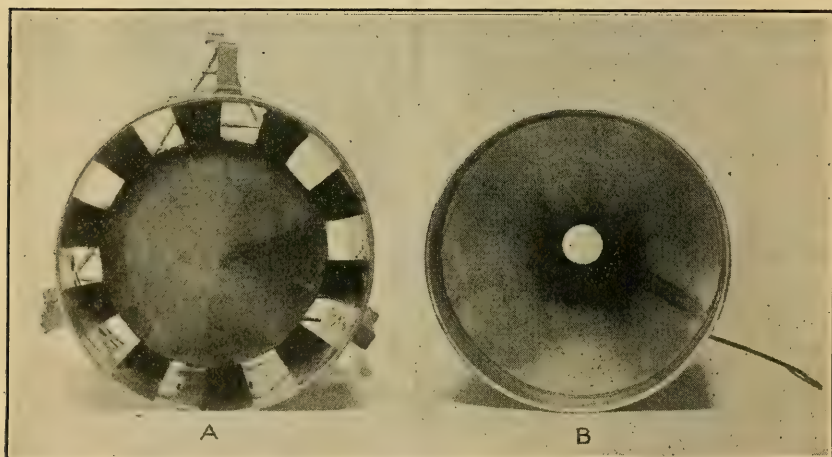


FIG. 3.—A, Top view of lower cylinder showing cone and arrangement of ducts and openings. B, Top view of upper cylinder showing hopper and gate (open).

comprising the original sample. If the correct proportions of the original factors are retained, it is not an indication of failure on the part of the device if the grain or other material is not divided into absolutely equal parts every time it is run through the sampler, the essential feature being the retention of the correct proportion of the factors of the original sample.

OPERATION.

After the device is set up with the cylinders, legs, and pans in correct position, and the gate in the hopper closed and locked, the sample to be divided is poured into the upper hopper.

Then the gate should be opened and swung clear of the opening, that the sample may fall through the opening in the hopper onto the point of the cone, where it slides over the entire surface of the cone.

in a shallow sheet and is divided into as many streams as there are spaces between the partitions at the base of the cone. As every alternate stream falls into one pan, and the intermediate streams are diverted into the other pan, the sample will be divided into approximately equal parts. In order to further divide the sample, it will be necessary only to close the gate and pour the contents of one of the pans—the lower pan will be found to be more convenient to use for this purpose—into the hopper, replace the pan, open the gate, and let that half of the original sample run through the device again. This action can be repeated, pouring always from the same pan, until the quantity of the sample deposited in one pan is the amount desired for analysis. By various combinations, pouring from

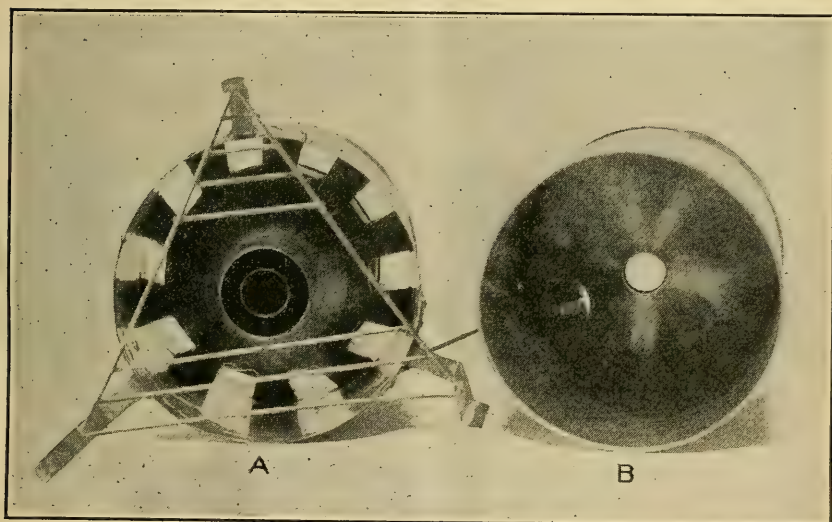


FIG. 4.—A, Bottom view of lower cylinder, showing spout at bottom of funnel and shield surrounding this spout. B, Bottom view, upper cylinder, showing bottom of hopper with gate open.

the same pan every time, as described, or by sometimes using the other, almost any desired size of sample can be obtained,¹ provided the entire contents of the pan being emptied are poured into the upper hopper each time.

For instance, if the weight of the original sample is 1,000 grams, and it is desired to obtain approximately 30 grams for analysis, the sample should be poured through, or "cut" as it is commonly called, five times. The first cut starts with 1,000 grams, giving 500 grams in each pan; the second cut starts with 500 grams, giving 250 grams in the pan just emptied, and 750 grams in the other; the third cut

¹ U. S. Department of Agriculture Bulletin 574 will be found convenient for use in grain grading in connection with this apparatus, as it contains tables of the conversion of the weights of mechanical separations of grains into percentages.

gives, respectively, 125 grams and 875 grams; the fourth cut, 62.5 grams and 937.5 grams; the fifth cut, 31.25 grams and 968.75 grams. These weights may vary slightly in amount, as previously explained, but this will not affect the accuracy of the portion.

CARE OF THE DEVICE.

As there are practically no moving parts to this device it requires little care except to keep it clean. If the openings around the base of the cone, or the ducts, are allowed to become choked or partially clogged by pieces of straw, cornéob, etc., the accuracy of the results may be vitally affected.

With the present device it is a simple matter to lift out the upper cylinder, examine the openings and ducts around the base of the cone, and remove any obstructions lodged there. This precaution

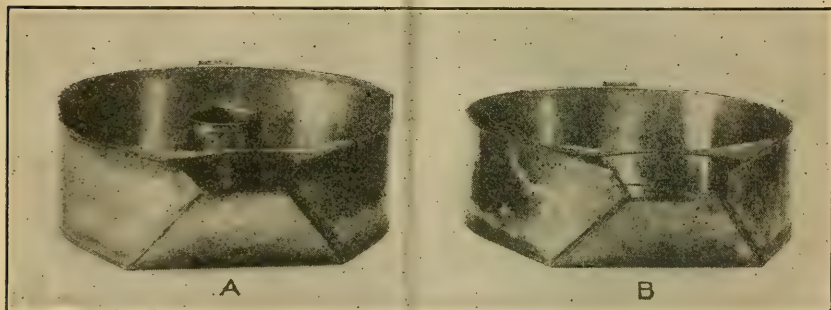


Fig. 5.—A, Upper pan, showing protected opening through which material passes to pan. B, Lower pan.

should never be neglected, as it affects the correctness of the sample and, by so doing, the analysis and grading of the grain in question.

HOW TO OBTAIN THE SAMPLER.

This device is covered by the same public-service patent as is the original standard apparatus described in Department of Agriculture Bulletin No. 287, and anyone in the United States is free to make and use it without the payment of a royalty.

A modified sampler made of block tin approximately 30 inches high and 10 inches in diameter, with 20 partitions spaced 1 inch apart around the base of the cone, which is considered a suitable size for grain-grading purposes, is now on the market. The design is so simple that any competent tinner or metal worker should be able to make it at about one-third the cost of the standard "Boerner Sampler." Working plans and specifications may be obtained from the Bureau of Markets, U. S. Department of Agriculture, Washington, D. C.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 858

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief



Washington, D. C.



July 16, 1920

REQUIREMENTS AND COST OF
PRODUCING MARKET MILK IN NORTHWESTERN
INDIANA.¹

By J. B. BAIN, *Dairy Husbandman*, and R. J. POSSON, *Market Milk Specialist*,
Dairy Division.

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CHARACTER AND SCOPE OF THE WORK.

In order to determine the requirements of milk production, to isolate and analyze the various factors so that methods could be recommended for reducing the cost of production, and to obtain data which would aid in improving general milk-production methods, the United States Department of Agriculture, through the Dairy Division of the Bureau of Animal Industry, began a series of studies in 1915. Since the intention of the department was to make these studies as thorough as possible, it was decided that the first step would be to obtain accurate data concerning the requirements for producing milk by practical dairy farmers in market-milk centers of the United States. Accordingly projects were organized to obtain detailed records on groups of dairies in various market-milk sections.

¹ The work was carried on in northwestern Indiana in cooperation with the Purdue University Agricultural Extension Department, and applies especially to milk supplied from that section for the Chicago market.

THE INDIANA PROJECT.

The project with which this publication deals was organized in Porter County, Ind., in cooperation with the Purdue University Agricultural Extension Department. The work was begun in August, 1915, and was continued for 2 years. The specialist employed by the two departments made monthly visits from September, 1915, to September, 1917, to each of a group of dairy farms in the northwestern part of the State. This section was selected because the milk from most of the farms in that vicinity was shipped and sold as market milk. All the farms included in this report were approximately 40 miles from Chicago and near-by cities. The many railroads running into Chicago through this territory afforded convenient shipping facilities.

The dairies were representative of dairy-farming conditions in that locality. Dairies conducted as hobbies or as breeding establishments were not included in the study, and with one exception the herds selected were owned or handled by resident farmers, many of whom lived on rented farms.

Although the figures obtained show what was required to produce market milk under the system of dairy management found in the section studied, and probably approximate the requirements in similar sections, they of course do not apply to dairying in other sections where other conditions and methods of management prevail.

The Chicago board of health inspected the dairies shipping milk to that city, and the equipment and methods used in the production and handling of the milk were subject to its supervision. Thus the figures given in this publication represent the requirements for producing milk in that section of Indiana for the Chicago market. The cost of production would have been somewhat different if either higher or lower grades of milk had been produced.

METHODS USED IN OBTAINING THE DATA.

The data obtained in this study are actual records obtained by regular visits of one day a month to 12 farms for 2 years and to 13 other farms for 1 year. The specialist recorded in detail all available information relative to the dairy business, including the amounts and classes of labor, feed and bedding used, the pasture cost, the amount of milk sold and that used on the farm, and the current expenses for the month. Accurate data on calves and first-hand information on methods of handling manure were systematically collected.

By obtaining records on every dairy regularly each month, the influence of unusual circumstances at the time of any particular visit was lessened, and by using the records of all the herds for each month average figures could be compiled for all the dairies and

representative data for each month, season, and year thus secured. Records were obtained the second year as a check on the first year's work and to increase the amount of data available for study.

At the beginning and end of each year the field agent took an inventory of the dairy buildings, livestock, and equipment used in the care of the herd and its products. On his regular monthly inspection tour he arrived at the first farm of a group in time to observe the first labor operations connected with the evening chores. With watch in hand he noted and recorded the exact minute each labor operation connected with the dairy was begun and ended. The labor operations during the next morning were recorded in the same manner.

Account was kept of the feeds that were being fed on the record day, including the kind, amount, cost, and description of each, and these were compared with the amounts recorded by the cow tester in the cow-testing association books.

The quantity of milk sold and receipts each month were obtained. In addition the milk used by the proprietor and his help or fed to calves was measured or weighed and used as a basis for determining the amount kept on the farm during the month.

The dairyman kept an itemized account of expenses which were incurred between the monthly visits, and these items were recorded. A monthly record was kept also of the purchase or sale of cows, calves, hides, outside bull service, and other miscellaneous information relating to the herd. The condition and methods of handling the manure were noted and reported each month.

When all the labor operations about the dairy had been completed for the day at the first farm, the specialist drove to the second farm in time to observe the labor operations connected with the evening chores. This program was followed until Saturday afternoon, when he returned to headquarters and finished his reports for the week's work. The same program was followed each week in the month, and each farm was visited every 30 days throughout the 2 years.

COMPARATIVE SKILL OF MANAGERS.

The comparative value of one dairyman with another, so far as ability to manage is concerned, is directly proportional to his comparative skill in feeding cows economically, managing labor efficiently, conserving the fertilizing value of manure, and producing a large volume of milk at low cost.

The charge for management is separate and distinct from the charge for the physical labor of the manager. Wherever costs are given for human labor they include only hired man's wages for work done by the manager. Therefore, it must be understood that wherever the terms "labor cost," "total cost of production," and

"net cost of production" are used, these terms do not include the charge for managerial ability. If it is desired to include managerial ability as a cost of production, when determined by any method selected, this amount may be added to the cost of production.

INFLUENCE OF SEASONS ON COST FACTORS.

Since the winter and summer seasons have a marked influence on the principal factors entering into the cost of producing milk, the results have been computed separately for those periods. The months from November to April, inclusive, represent the winter season, and from May to October the summer season. This division



FIG. 1.—Better breeding saved labor. The owner of this herd of cows, averaging 9,200 pounds of milk annually, had to feed and milk only 9 cows to obtain as much milk as 12 average association cows produced.

of time was based directly on the change in methods of herd management made in November and May.

The various tables in this bulletin are based upon figures obtained during the 2 years of the study, and all results are expressed in weighted averages in which the weights represent the relative importance of the separate items averaged.

DESCRIPTION OF HERDS.

During the first year the 16 herds on which records were tabulated contained 334 grade and purebred cows, mostly of the Holstein breed, which produced on the average 6,877 pounds of milk testing 3.8 per cent butterfat. In the 21 herds included in the study the second year there were 404 cows of approximately the same breeding

which averaged 6,987 pounds of milk testing 3.6 per cent butterfat. Grade cows made up 78 per cent of those included in the 2-year study and the rest were purebred. Complete records for 2 consecutive years were obtained on 12 of the herds whose owners cooperated throughout both years. The number of cows in the herds is obtained by adding the cows in each herd each month and dividing the total by 12.

TABLE 1.—*Number of cows in herds, average yearly production of milk, and calves produced each year.*

Herd No.	1915-16.			1916-17.		
	Cows in herd.	Calves produced per year.	Production per cow per year.	Cows in herd.	Calves produced per year.	Production per cow per year.
	<i>Number.</i>	<i>Number.</i>	<i>Pounds.</i>	<i>Number.</i>	<i>Number.</i>	<i>Pounds.</i>
102.....	13.6	13	6,139.9			
103.....	23.2	20	6,957.4	20.5	20	6,237.0
104.....	27.5	20	6,562.6			
106.....	25.8	17	7,091.0	28.0	26	6,890.8
107.....	16.1	13	6,331.4	18.7	21	6,162.3
108.....	28.4	23	6,309.8	29.8	30	5,660.6
109.....	18.9	14	7,622.5	19.4	17	7,866.2
110.....	11.5	13	6,710.0	11.2	9	5,778.1
111.....	18.4	17	9,063.0	13.7	13	9,083.4
112.....	28.9	25	4,915.0			
113.....	16.5	12	6,296.9	15.0	13	5,566.7
114.....	9.8	8	6,710.8	9.8	10	7,007.6
115.....	14.4	15	9,127.0	15.2	11	7,538.3
116.....	7.8	6	9,452.6	9.4	8	9,127.5
117.....				18.2	13	6,454.6
118.....	37.5	32	6,455.2			
119.....	35.2	18	7,306.6	31.8	33	7,750.8
121.....				17.8	13	7,166.3
122.....				13.8	16	6,682.8
123.....				17.3	17	7,935.8
124.....				24.8	22	8,156.2
125.....				22.5	19	9,106.0
126.....				27.6	27	6,947.0
127.....				15.6	17	4,779.4
128.....				23.9	24	5,465.4
Total.....	333.5	266		404.0	379	
Average.....	20.8	16.6	6,877.0	19.2	18.0	6,987.0

According to these figures 87 per cent of the cows produced a living calf each year.

TABLE 2.—*Per cent of cows dry during the winter, summer, and year.*

Period.	Winter.	Summer.	Year.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
First year.....	12.6	12.1	12.4
Second year.....	13.2	12.7	13.0

There was only a slight variation in the percentage of dry cows in the two seasons. This accounts for the uniformity of production of milk for the seasons. The calf crop was divided equally between seasons.

REQUIREMENTS FOR PRODUCING 100 POUNDS OF MILK.

It will be noted in Table 3 that with few exceptions the dollars and cents values have not been reported. Since prices of feed and labor change, results are more valuable when reported in a convertible form, such as pounds of feed and hours of labor. The average cost of hauling purchased concentrates to the dairies was \$1 a ton and the average cost of grinding was 7 cents a bushel for ear corn and 4 cents for shelled corn and other grains.

TABLE 3.—Unit requirements by seasons for producing 100 pounds of milk during the two years.

Item.	Winter.		Two win- ters.	Summer, ¹		Two sum- mers.
	1915-16	1916-17		1915-16	1916-17	
Feed:						
Purchased concentrates.....pounds..	24.5	16.5	20.0	15.9	13.2	14.5
Home-grown grains.....do.....	17.7	19.3	18.6	4.3	6.5	5.5
Total concentrates.....do.....	42.2	35.8	38.6	20.2	19.7	20.0
Noncommercial roughage.....do.....	23.2	13.0	17.4	.9	5.6	3.4
Commercial:						
Carbohydrate hay.....do.....	17.4	29.7	24.3	2.4	13.2	8.2
Legume hay.....do.....	23.8	26.0	25.1	14.9	16.5	15.8
Total dry roughage.....do.....	64.4	68.7	66.8	18.2	35.3	27.4
Silage and other succulent roughage.....do.....	153.2	143.2	147.6	56.4	63.2	60.1
Hauling and grinding concentrates.....dollars..	0.03	0.03	0.03	0.014	0.014	0.014
Pasture.....acres.....				.041	.039	.040
Bedding.....pounds.....	20.3	20.4	20.3			
Labor:						
Human labor.....hours.....	2.6	2.5	2.5	2.2	2.2	2.2
Horse labor.....do.....	.3	.2	.3	.2	.2	.2
Overhead and other costs:						
Building charges.....dollars..	0.132	0.104	0.116	0.131	0.114	0.122
Equipment charges and dairy supplies.....do.....	.081	.065	.072	.079	.071	.075
Herd charges:						
Taxes, insurance, veterinary, medicines, disinfectants, and cow-testing association.....dollars..	.044	.043	.043	.044	.047	.045
Interest on cow investment.....do.....	.079	.066	.072	.078	.073	.075
Cost of keeping bull.....do.....	.077	.056	.065	.066	.051	.058
Total.....do.....	.413	.334	.368	.398	.356	.375
Depreciation on cows.....do.....	.109		.017	.108		.018
Appreciation on cows.....do.....		.054			.060	
Total overhead and other costs.....do.....	.522	.280	.385	.506	.296	.393

¹ As the study was begun in August, 1915, the summer designated as 1915-16 includes September and October of 1915 and May, June, July, and August of 1916. The summer of 1916-17 includes the corresponding months of those years.

Because the inventories showed a depreciation on cows the first year and an increase the second, these items were not added to the sum of the overhead and other costs in order that they might be more easily considered separately. The fact that there was a depreciation shown on the herd for the first year and an increase the second is due to a combination of factors. When the last inventory was taken, the influence of the increase in market price of cattle during the second year was apparent. Especially was this true in the case of cows in their first and second lactation periods, on which there

seemed to be a greater increase in value than was warranted by production due to increased age.

On the other hand, due to the fact that most of the dairymen were replacing their poorer cows with more promising younger ones, the herds the second year contained a rather large proportion of heifers which had freshened for the first time, which accounts for the increase in value between the time they freshened and the time the second inventory was taken.

The difference between the overhead requirements per 100 pounds of milk for the two years, aside from the depreciation and appreciation on the cows, is due mostly to a greater average production the second year, which lowered the cost for each 100 pounds of milk produced.

The item of bull charges includes feed, labor, and overhead costs of keeping the bull. On account of the feed and labor being expressed in dollars and cents, a table showing in detail the unit requirements for keeping a bull in the winter and summer and for a year is presented on page 10. If desired, current rates and prices may be applied to these records.

CREDITS FOR EACH 100 POUNDS OF MILK PRODUCED.

CALVES.

The credits for calves amounted during the winter periods to 0.012 of one calf for each 100 pounds of milk produced and during the summer periods to 0.013 of one calf. In this case the credit amounted to \$0.12 for each 100 pounds of milk produced in winter, and \$0.13 per 100 pounds of summer milk. This was based on the price for which they sold for veal or at the prevailing local price for heifer calves at birth.

MANURE.

For each 100 pounds of milk produced in the two winter periods, there was a credit of 332 pounds of manure, including bedding which contained 1.62 pounds nitrogen, 0.53 pound commercial phosphoric acid, and 1.66 pounds potash. This was computed from the manurial constituents in the feed and the methods of handling the manure.

For each 100 pounds of milk produced in the summer there was a credit of 54 pounds of manure, which was assumed to be of the same quality as that produced in the winter and contained 0.26 pound nitrogen, 0.08 pound commercial phosphoric acid, and 0.24 pound potash. The methods used in determining the credit for manure in the winter and summer periods are treated in detail, beginning on page 23 of this bulletin.

REQUIREMENTS FOR KEEPING A COW ONE YEAR.

Since a large part of the feed required in the summer was supplied in the form of pasture grass, much less feed was consumed in the barn than during the winter. Attention is directed to the fact that the rations fed in the barn by these dairymen contained a relatively larger proportion of high-protein concentrates and legumes in the summer than in the winter. When the pastures became short, those dairymen who had alfalfa and clover fed them, while those who did not have legumes purchased concentrates in order to maintain the production of their cows.

TABLE 4.—Quantities of various classes of feeds required and expenses incurred for keeping a cow during each season and for the entire year.

Item.	Winter.	Summer.	Entire year.
Number of cows.....	740.0	734.8	737.5
Average production.....pounds..	3,540	3,397	6,937
Feed:			
Purchased concentrates.....do....	707	491	1,198
Home-grown grains.....do....	659	187	848
Total concentrates.....do....	1,366	678	2,046
Noncommercial roughage.....do....	616	116	734
Commercial carbohydrate hay.....do....	862	278	1,143
Legume hay.....do....	887	536	1,424
Total dry roughage.....do....	2,365	930	3,301
Silage and other succulent roughage.....do....	5,224	2,042	7,276
Hauling and grinding concentrates.....dollars..	1.06	.45	1.53
Pasture.....acres.....		1.36	1.36
Bedding.....pounds.....	720		720
Labor:			
Human labor.....hours..	90.1	74.4	164.5
Horse labor.....do....	8.9	7.4	16.2
Overhead and other costs:			
Building charges.....dollars..	4.12	4.14	8.27
Equipment charges and dairy supplies.....do....	2.53	2.55	5.09
Herd charges:			
Taxes, insurance, veterinary, medicine, disinfectants, and cow-testing association.....dollars..	1.55	1.56	3.12
Interest on cow investment.....do....	2.55	2.57	5.14
Cost of keeping bull.....do....	2.32	1.97	4.29
Total.....do....	13.07	12.79	25.91
Depreciation on cows.....do....	.60	.60	1.20
Appreciation on cows.....do....			
Total overhead and other costs.....do....	13.67	13.39	27.11

Approximately 16 hours less human labor was performed per cow in the summer period than in the winter. It may be seen in Table 17, which shows the labor used in producing, handling, and hauling the milk, that this difference is due to more work being done in the winter when the cows were in the barn than in the summer when on pasture. The labor required for handling and hauling the milk was practically the same for both seasons.

A more detailed account of the units of cost will be found in the back part of this bulletin where the feed, labor, overhead, and other costs required for all the milk produced by the herds during the two years' study are reported in detail.

CREDITS PER COW FOR THE WINTER, SUMMER, AND ENTIRE YEAR.

During the first year of this study living calves were produced by 80 per cent of the cows, while 94 per cent produced live calves the second year. The average value of these calves was \$10.08. Most of the heifer calves were raised by the dairymen who produced them, but some were sold to neighbors to be raised. The grade bull calves were vealed and usually sold for about \$10 each, which was also about the average price of heifer calves which were sold to be raised. Since the purebred cows were given the same values as grade cows of like producing ability, the purebred bull calves were credited to the herds at what they would have been worth when 4 days old to fatten for veal, and, similarly, the purebred heifer calves were given the same value as grade heifer calves. The value of milk consumed by veal calves was covered in the selling price of the calves.

CREDIT FOR MANURE.

The average credit allowed per cow per year for manure and bedding included the manure from the bulls, and represents what was or could have been saved by practicable methods of handling. Since the total cost of keeping bulls is charged against the cows under overhead and other costs, the manure from the bulls is included as a direct credit to the herd. Of this total credit per cow 5.6 tons of manure and bedding were produced by the cows alone in the winter, and 0.7 of a ton of manure in the summer, amounting to 6.3 tons of manure and bedding per cow per year. (See page 23.)

TABLE 5.—Credits for calves and manure per cow (bull manure included), and fertilizing constituents contained in the manure and bedding.

Item.	Winter.	Summer.	Year.
Calves per cow.....	0.44	0.43	0.87
Manure per cow..... tons..	5.9	0.9	6.8
Constituents of manure:			
Nitrogen..... pounds..	57.4	8.9	66.3
Phosphoric acid..... do...	18.6	2.8	21.4
Potash..... do.....	58.8	8.2	67.0

REQUIREMENTS FOR KEEPING A BULL.

The record on one bull for one month, called a bull-month, was taken as a working unit. The number of bull-months for the winter and summer periods was the same.

On 10 of the farms the bulls were allowed to run with the cows, and on some of the others were either put on cables or tethered out in the summer and so required little attention, which accounts for the smaller amount of labor per bull in the summer period. In some cases the bulls which ran with the cows were not put into the barns at all while the pasture was plentiful, and received no attention other than being driven from the pasture with the herd.

TABLE 6.—Requirements for keeping a bull by seasons based on averages obtained from the equivalent of 33 bulls varying from 1 year old to maturity and kept for fractional parts of a year.

Item.	Average of two winters.	Average of two summers.	Average of two years.
Feed:			
Concentrates—			
Purchased.....pounds..	335.0	307.7	642.7
Home grown.....do.....	518.7	238.3	757.0
Total concentrates.....	853.7	546.0	1,399.7
Dry roughage—			
Noncommercial.....do.....	528.7	37.2	565.9
Commercial carbohydrate.....do.....	853.4	733.3	1,586.7
Legume.....do.....	934.7	938.1	1,872.8
Total dry roughage.....	2,316.8	1,708.6	4,025.4
Succulent roughage.....do.....	4,331.2	1,671.6	6,002.8
Bedding.....do.....	645.4		645.4
Pasture.....do.....		\$4.56	\$4.56
Human labor.....hours.....	23.8	11.9	35.7
Overhead costs:			
Interest on bull investment.....	\$7.83	\$7.83	\$15.66
Depreciation on bull.....	2.89	2.89	5.79
Bull's share of buildings.....	4.12	4.14	8.26
Total overhead costs.....	14.84	14.86	29.71

The reason why the yearly average depreciation per bull amounted to only \$5.79 was that many of the bulls increased in size after being taken into the herds, and when sold for beef brought as much as or more than the initial cost.

SUMMARY STATEMENT OF COSTS FOR THE TWO YEARS, BY SEASONS.

The cost of the various requirements for keeping a cow and for producing 100 pounds of milk during the 2 years is presented by seasons in Tables 7 and 8. During the second winter and summer the total cost, except the herd inventory variation, was \$7.32 and \$3.25 more per cow and 6 cents and 16 cents more per 100 pounds of milk, respectively, than during the corresponding seasons of the first year. The cost per cow and per 100 pounds of milk did not increase in the same proportion the second year because of the variation in seasonal production of the herds. That there was an increase of only 6 cents in the cost of 100 pounds of milk during the second winter over that of the first, as compared with \$7.32 increase in the cost of keeping a cow during the same period, is the direct result of the higher production per cow during the second winter.

The high increase in the cost of producing 100 pounds of milk during the summer of the second year and the comparatively small increase in the cost per cow, is due to a lower average production during this period than during the summer of the first year. Higher feed prices the second year account in most part for the higher cost per cow during that period.

TABLE 7.—*Cost of producing 100 pounds of milk during four seasons, charge for management not included.*

Item.	1915-16		1916-17	
	Winter.	Summer.	Winter.	Summer.
Feed cost.....	\$1.149	\$0.466	\$1.28	\$0.702
Pasture cost.....		.340		.275
Bedding cost.....	.031		.03	
Labor cost.....	.391	.309	.331	.312
Overhead and other costs, except herd inventory variation.....	.414	.399	.334	.357
Total cost except herd inventory variation.....	1.985	1.514	2.048	1.676
Appreciation on cows.....			.054	.059
Depreciation on cows.....	.109	.108		
Total cost.....	2.094	1.622	1.994	1.617
Credit for calves.....	.111	.109	.134	.148
Credit for cow manure and used bedding.....	.397	.052	.520	.075
Credit for bull manure.....	.021	.012	.026	.016
Total credit.....	.529	.173	.680	.239
Net cost.....	1.565	1.449	1.314	1.378

Higher feed prices during the second year were almost offset by the herd appreciation, together with the increased production of



FIG. 2.—Well-lighted stables kept the hired men contented and promoted health in the cows.

milk. The total cost was 10 cents less per 100 pounds of milk the second winter than it was the first, and was approximately the same for the two summers.

Calves sold for a higher price the second year and the fertilizing constituents in the manure and bedding also had a higher value on account of the higher price of commercial fertilizers.

The higher credit allowed for manure in the winter tended to equalize the net cost for the winter and summer periods. The values per pound at which the fertilizing constituents in the manure and used bedding were credited to the cows the first year were 18 cents for nitrogen, $4\frac{1}{2}$ cents for phosphoric acid, and 5 cents for potash, as compared with 25 cents, 6 cents, and $6\frac{1}{2}$ cents a pound for the same constituents during the second year. The value of a ton of manure the first year was found to be \$2.38 as compared with \$3.29 for the second year.

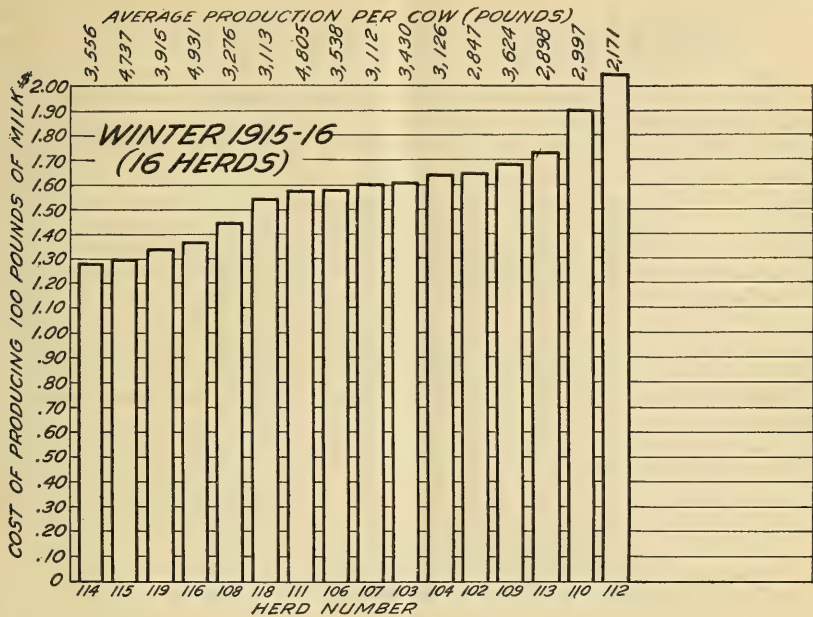
TABLE 8.—*Cost of keeping a cow during four seasons, charge for management not included.*

Item.	1915-16.		1916-17.	
	Winter.	Summer.	Winter.	Summer.
Feed cost.....	\$39.10	\$16.21	\$46.78	\$23.41
Pasture cost.....		11.82		9.16
Bedding cost.....	1.05		1.56	
Labor cost.....	13.29	10.73	14.30	11.40
Overhead and other costs, except herd inventory variation.....	14.11	13.88	12.23	11.92
Total cost except herd inventory variation.....	67.55	52.64	74.87	55.89
Appreciation on cows.....			1.98	1.99
Depreciation on cows.....	3.71	3.75		
Total cost.....	71.26	56.39	72.89	53.90
Credit for calves.....	3.77	3.81	4.90	4.93
Credit for cow manure and used bedding.....	13.52	1.75	19.02	2.50
Credit for bull manure.....	.70	.45	.96	.54
Total credit.....	17.99	6.01	24.88	7.97
Net cost.....	53.27	50.38	48.01	45.93

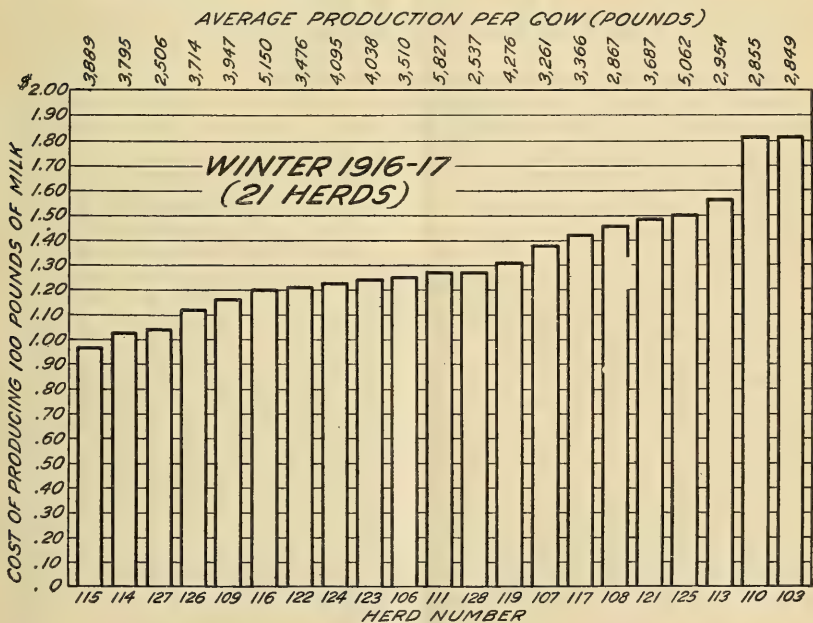
COST OF PRODUCTION BY HERDS AND BY SEASONS.

The varying net costs of producing 100 pounds of milk, the average number of cows and the average production of milk per cow are shown for each herd during the two seasons of each year in figures 1 and 2. It will be noted that although there is a tendency toward lower cost of production for the higher-producing herds this rule does not always apply. In some cases the other factors of cost outweigh the influence of high production, or, again, the high production may have been obtained at too great an expense.

This may have been caused by feeding the cows beyond their ability to produce economically. For example, in the winter of 1916-17 Herd 127 with a 6-months' production of only 2,506 pounds per cow, produced milk at \$1.04 per 100 pounds while it cost \$1.50 to produce 100 pounds from Herd 125, in which the cows made an average winter production of 5,062 pounds of milk. The low cost in Herd 127 was made possible by a low overhead due to small investment in buildings and cows and a low feed cost, while Herd 125 showed high overhead costs, due to expensive buildings and cattle and a high feed cost, due to exceptionally heavy feeding. But to obtain the income on an equal volume of milk it would have been necessary for the owner of Herd 127 to keep two cows for every cow kept in Herd 125.



9.2 14.0 33.8 8.0 28.2 36.8 19.0 26.7 16.3 24.0 26.7 14.2 19.0 16.8 11.7 30.7
AVERAGE NUMBER OF COWS IN HERD



15.2 10.0 15.0 28.0 19.8 9.5 14.0 24.7 18.0 28.3 11.2 23.3 34.3 18.5 17.7 29.8 18.2 22.3 14.8 11.7 20.7
AVERAGE NUMBER OF COWS IN HERD

FIG. 3.—Average production per cow and cost of producing 100 pounds of milk in winter.

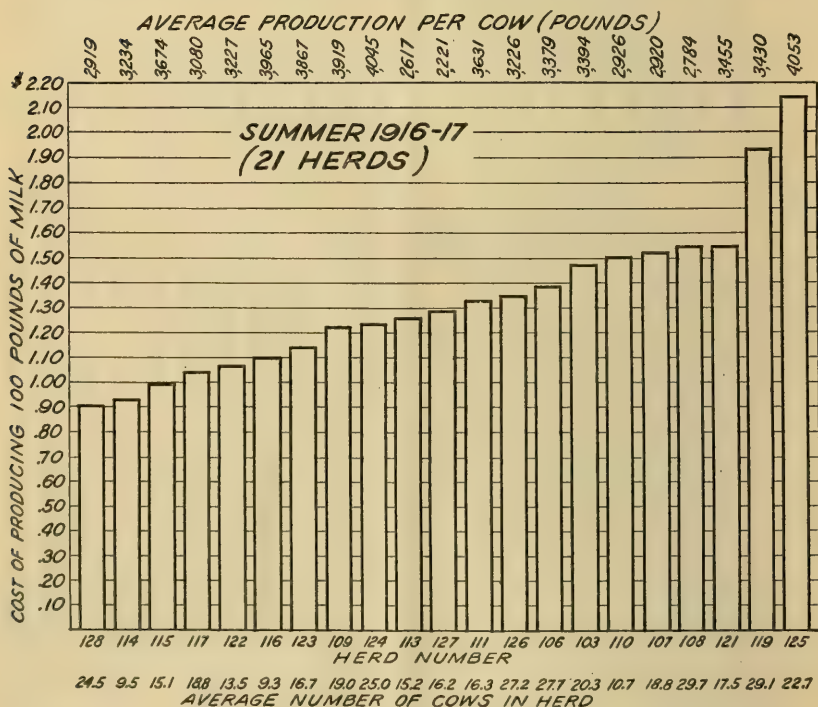
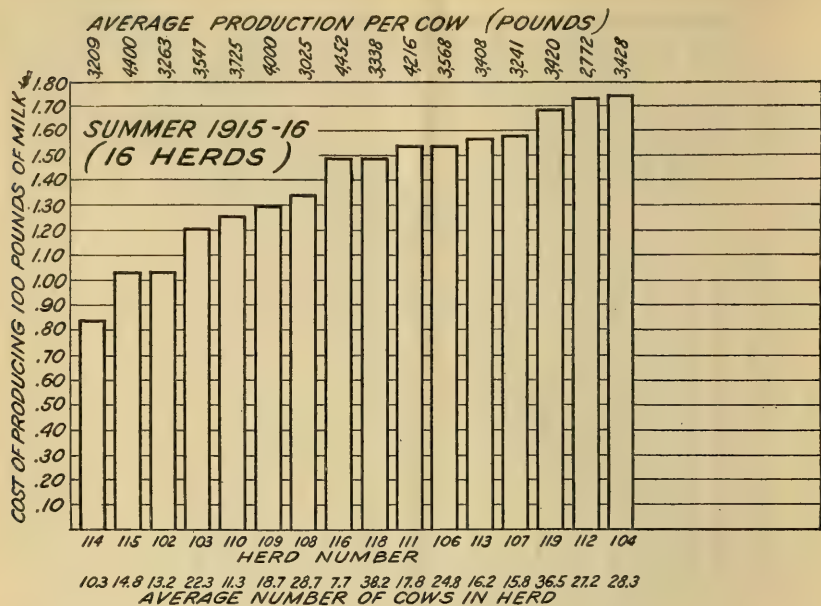


Fig. 4.—Average production per cow and cost of producing 100 pounds of milk in summer.

The average cost of producing 100 pounds of milk from all the cows on which records were obtained in each of the winter and summer seasons can be found in the financial statement in Table 7.

DETERMINATION OF BULK LINE COST.

During the last 2 or 3 years a number of methods have been developed for determining the price of milk on a cost of production basis, and these plans are being used by a number of communities as a basis for milk prices. If in these plans the figures that are used merely represent the average cost of production, it is evident that practically one-half of the producers whose costs are above the average will not be sufficiently well compensated for their efforts. This will have a tendency to discourage production and decrease the available supply. On the other hand, it would not be advisable to pay a price based on the least economical producer since this would encourage his poor methods and stimulate an overproduction by the more economical producers.

Between these two extremes there is a point under which the greatest volume of milk is produced. Such a point or line of demarcation has been designated as the bulk line. This bulk line, shown in figures 5 and 6, is arbitrarily placed to eliminate that milk which is produced at a relatively higher cost as compared with the bulk of the milk produced, and yet is high enough to stimulate a corresponding increase in the low-cost herds.

If these figures are used in determining a price for milk it is questionable whether the credit for appreciation on cows should be allowed, since it is doubtful whether normal market conditions would ever produce an appreciation on cows. Furthermore the appreciation in the value of cows due to market conditions gives a "paper credit" rather than real credit since the cows were not actually sold.

PERCENTAGE COMPARISON OF FACTORS IN MILK PRODUCTION.

With the exception of November, the gross feed and bedding cost in Table 9 ran higher during the winter months than during the summer months. With this one exception there was apparently no large variation in the feed cost from month to month within any season during the two years.

Since the manure and soiled bedding resulted from the feed and bedding used by the cows, the credit for these latter items was subtracted from the cost of feed and bedding when making a comparison of the net feed and bedding cost by months. The cost of feed and bedding minus the credit for manure and bedding gave the net feed and bedding cost. When the credit for manure and bedding was subtracted, there was no large variation in the cost of feed from month to month throughout the two years with the exception of

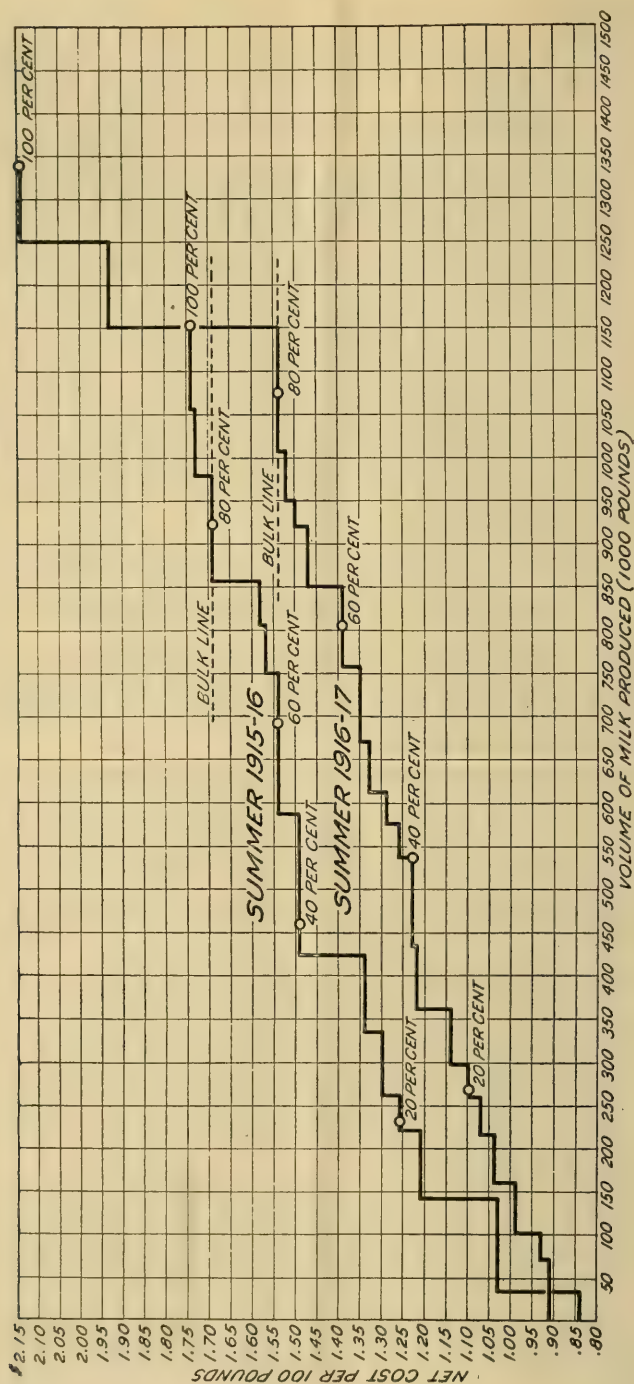


FIG. 5.—Volume of milk produced and the net cost per 100 pounds in summer.

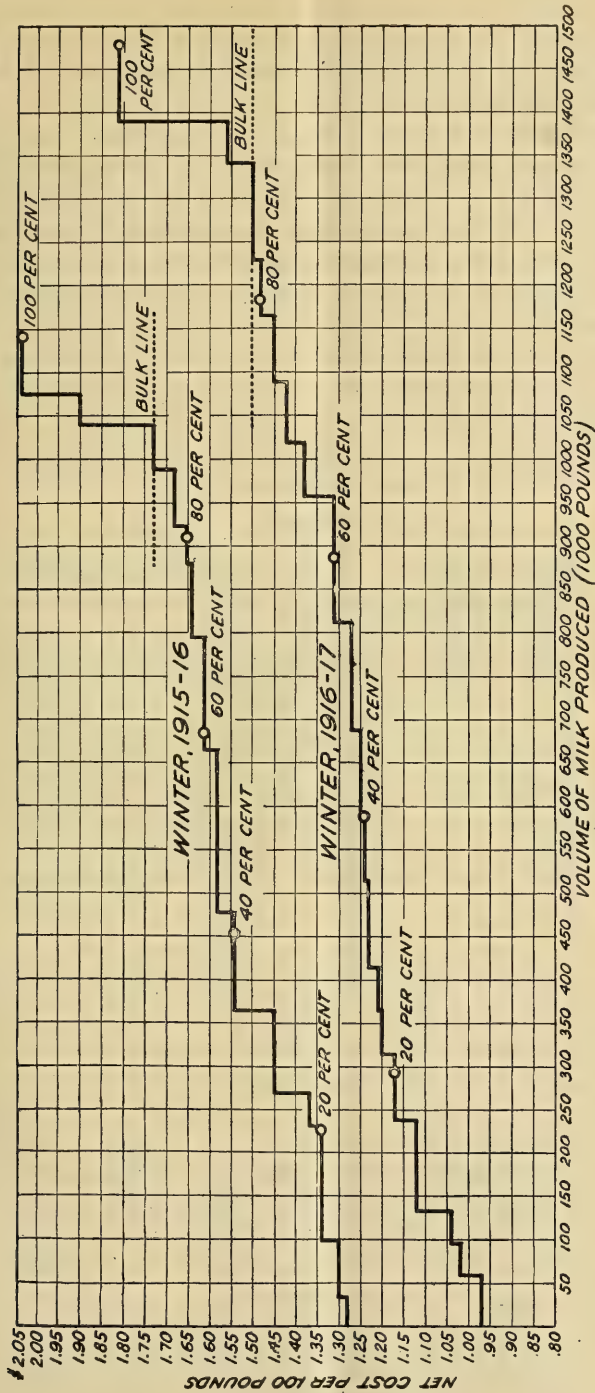


FIG. 6.—Volume of milk produced and the net cost per 100 pounds in winter.

November. The lower feed cost for November was accentuated because the credit for manure and bedding was divided evenly among the 6 winter months regardless of the amount of feed consumed in the different months.

The human labor performed each month, especially when expressed on the "per cow" basis, was fairly constant within each seasonal period. The labor required to produce 100 pounds of milk fluctuated a little more, due to the variation in the amount of milk produced. It required 0.4 of an hour more human labor to produce 100 pounds of milk in the winter of the first year than in the summer, as compared with a difference of 0.3 of an hour for the second year. Attention is directed to the fact that there was little variation in the average monthly labor required to produce 100 pounds of milk or to keep a cow in corresponding seasons of both years.

TABLE 9.—*Monthly and seasonal distribution of milk prices, milk produced, feed cost and labor required.*

YEAR 1915-16.

Month, season, and year.	Income per 100 pounds milk less freight.	Per cent of year's income from milk sold and used.	Per cent of year's milk sold and used.	Per cent of year's feed and bedding cost.	Feed and bedding cost less manure and bedding credit.	Human labor.		Horse labor.	
						Per 100 pounds milk.	Per cow.	Per 100 pounds milk.	Per cow.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>
May.....	\$1.57	7.9	8.8	6.4	9.7	2.0	12.7	0.3	1.6
June.....	1.41	6.9	8.6	7.3	7.3	2.1	12.3	.3	1.6
July.....	1.72	7.8	8.0	6.4	7.9	2.4	13.2	.3	1.8
August.....	1.81	8.0	7.7	7.1	7.5	2.4	12.7	.2	1.3
September.....	1.76	8.5	8.4	6.7	8.4	2.1	12.0	.2	1.2
October.....	1.72	8.7	8.8	6.9	10.1	2.2	13.0	.2	1.2
Summer.....	1.66	47.8	50.3	40.8	50.9	2.2	12.6	.2	1.5
November.....	1.91	8.9	8.2	7.2	5.9	2.6	13.6	.3	1.3
December.....	1.92	9.1	8.3	10.2	8.1	2.7	14.9	.3	1.4
January.....	1.86	8.8	8.2	10.9	8.7	2.9	16.2	.3	1.4
February.....	1.79	8.3	8.1	9.7	7.7	2.6	14.6	.3	1.5
March.....	1.76	8.7	8.6	10.8	9.4	2.6	16.1	.3	1.6
April.....	1.77	8.4	8.3	10.4	9.3	2.5	14.5	.3	1.8
Winter.....	1.84	52.2	49.7	59.2	49.1	2.6	15.0	.3	1.5
Year.....	1.75	100.0	100.0	100.0	100.0	2.4	13.8	.3	1.5

YEAR 1916-17.

May.....	\$2.08	8.8	9.2	7.5	7.8	2.0	13.0	.2	1.0
June.....	1.77	7.1	8.7	5.8	9.0	1.8	11.3	.2	.9
July.....	2.28	8.6	8.2	6.3	7.7	2.0	11.6	.2	1.0
August.....	2.45	7.7	6.9	6.0	8.6	2.4	11.5	.2	1.0
September.....	1.85	6.1	7.2	6.7	8.1	2.5	12.3	.2	1.0
October.....	2.15	7.4	7.5	7.8	8.5	2.6	13.3	.2	1.1
Summer.....	2.09	45.7	47.7	40.1	49.7	2.2	12.2	.2	1.0
November.....	2.30	8.1	7.6	8.4	4.9	2.7	14.0	.2	1.2
December.....	2.49	9.7	8.5	9.9	8.8	2.7	15.8	.3	1.6
January.....	2.16	9.1	9.1	10.3	9.8	2.6	16.0	.3	1.6
February.....	2.07	8.4	8.8	9.7	8.1	2.4	15.0	.2	1.4
March.....	1.97	8.5	9.4	10.8	9.6	2.4	15.9	.2	1.5
April.....	2.54	10.5	8.9	10.8	9.1	2.1	13.6	.2	1.4
Winter.....	2.25	54.3	52.3	59.9	50.3	2.5	15.1	.2	1.4
Year.....	2.17	100.0	100.0	100.0	100.0	2.3	13.6	.2	1.2

The figures in Table 9 indicate that there is no close relation between the monthly cost of milk and the monthly price received for it during the 2 years. There was no regular variation in the monthly cost within any of the seasons except a little lower cost in November, indicating that the cost in the section in which these records were obtained was about the same from month to month during the summer or during the winter season. The price received for the milk, however fluctuated sharply from month to month.

The methods by which the amounts and values of the various items considered in these studies were determined will be discussed briefly here under the several heads of feed, labor, and overhead and other costs.

FACTORS INVOLVED IN THE COST OF PRODUCING MILK.

FEED.

EXPLANATION OF TERMS.

Concentrates is a term applied to grains and by-products from the milling of grains or seeds, comprising those feeds containing a large amount of nutritive material in a relatively small bulk.

Dry roughage includes various hays and other coarse feeding stuffs.

Noncommercial dry roughage is applied to corn stover and corn fodder and any other dry roughage for which price quotations are not given in the trade papers.

Leguminous roughage includes alfalfa, cowpea, clover, and other legume hays having such a small percentage of other grasses as not materially to affect the protein content.

Commercial carbohydrate hay includes all commercial hays except those classified as leguminous roughage.

QUANTITY OF FEED USED.

The amounts of the different kinds of feed were based on the weights obtained for the total amount which each herd received in one full day. The feed was weighed for each herd on one day of every month, while this study was being made. The weighing of the feed, with the exception of that which three herds received the first year, was done by the cow tester of the Porter County Cow-Testing Association. The field agent who also made the visits to each herd every month, weighed the feed for Herds 114, 115, and 116 during the first year and checked up closely on the tester's weights for all herds each month for both years.

FEED PRICES.

The home-grown feeds were figured at market prices on the farm plus any expense connected with them, such as grinding, hauling, and baling. Oats and ear corn were hauled to the mill to be ground. Limited barn space made it necessary for some of the dairymen to

bale their straw and hay. The purchased feeds were figured at their actual cost at the feed store or on the track, plus the cost of hauling them home. The same methods were used in figuring the value of bedding. However, some of the bedding consisted of refuse hay and shredded corn stover left in the mangers, for which no charge was made.

TABLE 10.—Average cost of feed per ton on the farm, including cost of grinding home-grown grains and hauling purchased concentrates.

Feed.	1915-16.		1916-17.	
	Winter.	Summer.	Winter.	Summer.
Purchased concentrates.....	\$28.51	\$27.27	\$35.89	\$36.58
Home-grown grain.....	21.44	23.66	33.95	40.23
Commercial carbohydrate hay.....	10.20	7.59	10.90	11.41
Noncommercial roughage.....	5.13	7.35	5.95	5.28
Legume hay.....	12.83	9.57	12.89	13.34
Succulent roughage.....	4.03	4.08	4.03	4.08

PASTURE.

The cost of pasture was determined by adding to the interest on the investment in land the cost of maintaining fences, and incidentals, such as seeding, cutting weeds, etc. The investment in land was obtained by subtracting the value per acre of the improvements on the farm, as determined by prorating their value in accordance with the quality of the different classes of land on a farm, from the improved value per acre. In one or two instances where land was rented at so much an acre for pasturage purposes, this value was taken. The cost of pasture was distributed over the 6 summer months as nearly as possible in proportion to the quantity of feed the herd received from the grass each month.

LABOR.

The amount of different kinds of labor was obtained by timing the work performed during one entire day every month in each dairy. The rate per hour was computed each month for every farm on a basis of the number of hours available for work each month and the wages paid by that farmer, and any other expenses connected with the hired help, such as board and room or having a horse kept. The number of hours was found by using the average length of the working day, with time out for meals, and hours of work performed on Sunday. Board for hired help was computed on the basis of local rates.

When these costs were tabulated, no charge for management was included. The labor performed by the managers was charged to the herds at hired men's rates. Although a charge for management should be included in the requirements for milk production, no satisfactory method was found for determining what this should be for all the dairies.

TABLE 11.—Average labor rates per hour.

Class of labor.	1915-16.		1916-17.	
	Winter.	Summer.	Winter.	Summer.
Manager ¹	\$0.153	\$0.149	\$0.160	\$0.164
Hired man.....	.129	.118	.137	.140
Woman.....	.128	.122	.157	.152
Boy and girl.....	.088	.081	.100	.090
Horse.....	.100	.100	.100	.100

¹ The rate per hour for the labor performed by the managers is a little higher than that for hired men because as a rule the managers would have commanded a considerably higher monthly wage as hired men than the men they hired. No charge for management, however, is included in this rate.

DISTRIBUTION OF LABOR.

The summaries in Table 12 show that 80 and 76 per cent of the total labor for the winter and summer, respectively, was required to



FIG. 7.—Meeting an early train 365 mornings in the year was an important item of labor.

do work in the barn, such as feeding, cleaning, and milking; also, that the main difference in the amount of labor performed for 100 pounds of milk in the summer and winter was due to a difference in the production labor for the two seasons.

TABLE 12.—Human labor used in producing, handling, and hauling 100 pounds of milk to the shipping platform.

Kind of work	Winter.				Two winters.		Summer.				Two summers.	
	1915-16.		1916-17.				1915-16.		1916-17.			
	Hours.	Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.	Per cent.	Hours.	Per cent.
Production.....	2.12	80.2	1.98	79.9	2.04	80.0	1.65	75.8	1.69	77.1	1.67	76.5
Handling.....	.31	11.8	.30	12.3	.31	12.1	.33	15.2	.32	14.6	.33	14.9
Hauling.....	.21	8.0	.19	7.8	.20	7.9	.20	9.0	.18	8.3	.19	8.6
Total. . . .	2.64	100.0	2.47	100.0	2.55	100.0	2.18	100.0	2.19	100.0	2.19	100.0

TABLE 13.—*Per cent and hours of labor performed by each class of help in the production of 100 pounds of milk.*

WINTER.

Class of labor.	Distribution of work performed.			Labor per 100 pounds milk.		
	1915-16.	1916-17.	Average.	1915-16.	1916-17.	Average.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>
Managers.....	39.9	47.2	43.5	1.05	1.17	1.12
Hired men.....	49.4	33.0	41.2	1.30	.81	1.03
Total man labor.....	89.3	80.2	84.7	2.35	1.97	2.15
Women.....	8.2	14.2	11.2	.22	.35	.29
Boys and girls.....	2.5	5.6	4.1	.07	.14	.11
Total.....	100.0	100.0	100.0	2.64	2.47	2.55

SUMMER.

Managers.....	40.2	42.6	41.4	0.88	0.93	0.91
Hired men.....	43.6	35.0	39.3	.95	.77	.85
Total man labor.....	83.8	77.6	80.7	1.83	1.70	1.76
Women.....	13.0	13.4	13.2	.28	.29	.29
Boys and girls.....	3.2	9.0	6.1	.07	.20	.14
Total.....	100.0	100.0	100.0	2.18	2.19	2.19

During the first winter studied, as shown in Table 13, the managers did 39.9 per cent of the dairy work, and the hired men performed 49.4 per cent of it. The remaining 10.7 per cent was done mostly by the women. A comparative study of the percentage of labor performed by each class of help for each season shows how the labor of the manager and his family replaced that of the hired help which was attracted to industrial plants by higher wages. The women limited their efforts for the most part to milking and to washing utensils, and actual observation showed that in these operations they were just as efficient as the men or even more so.

OVERHEAD AND OTHER COSTS.

HERD.

A pound of milk from a purebred cow was worth no more than from a grade cow. Purebred cows were inventoried at fair prices for grade animals of similar producing ability, and the purebred calves were given corresponding grade values. This method eliminated both the higher overhead charge on cattle and the larger credit for the purebred value of calves.

Each herd was inventoried the first month, and interest at the rate of 6 per cent was computed on the value of the cows and bulls at that time. An account was kept of all animals coming in or going out of the herd and what they were worth at that time. Losses due to death in the herd were accounted for in the difference between the inventories. At the end of the year another inventory was taken

and the difference between this, plus the receipts for the outgoing animals and hides sold, and the first inventory, plus the value of incoming animals at the time they entered the herd during the year, constituted the depreciation or appreciation on the herd for the year. As in the case of feed and labor the records on the cows and bulls were kept separate for each herd in order that the requirements for producing a certain quantity of milk, aside from the cost of keeping bulls, would be available for study. Records were obtained of the actual costs of taxes, insurance, veterinary services, medicine, disinfectants, and cow-testing dues.

BUILDINGS.

The buildings, including silos, were inventoried at the beginning and the end of the year and interest at 5 per cent was figured on the value of those used for the cows, as shown by the first inventory. The first inventory value, divided by the years it was estimated the buildings would remain in a usable condition, constituted the depreciation charge. The cost of painting, shingling, and repairs was computed, and wherever possible the exact cost was obtained and recorded under "Upkeep and repairs." The dairies were charged with their share of the actual taxes and insurance paid, as shown by county records and insurance policies.

EQUIPMENT.

The dairy equipment was inventoried at the beginning and the end of the year. Interest at 6 per cent was charged on the first inventory value. The difference between the first inventory, plus equipment purchased, and the one taken at the end of the year, plus equipment sold, was recorded as depreciation. A list of all repairs on equipment and dairy supplies purchased was kept by the dairymen and recorded each month. The taxes on equipment, as for cattle and buildings, were taken from the county records.

CREDIT FOR MANURE.

In the computation of credit to be allowed for winter manure, six factors were considered, namely, the fertilizing constituents contained in the feed consumed; the proportion of nitrogen, phosphoric acid, and potash not utilized in the bodies of the cows but voided in the manure; the per cent of the total manure which was voided in the barn; the per cent saved in handling and storing; the nitrogen, phosphoric acid, and potash in the bedding; and the value of these constituents in the manure and bedding at wholesale prices for commercial fertilizers.

The small quantity of manure saved in the barn in the summer was presumed to be of the same quality as that produced in winter,

and was credited to the cows at the same price per ton as winter manure.

A method of crediting manure was sought which would give definite figures on its fertilizing value, taking into consideration the manure available for return to the land, the method by which it was handled, and its constituents. It is believed that the system used is just and applicable. If, however, on certain individual farms or in certain localities the needs of the soil would not warrant the payment of market prices for all or part of the fertilizing constituents in the manure, adjustments should be made accordingly.

DETERMINATION OF FERTILIZING CONSTITUENTS IN FEED AND MANURE.

The amounts of nitrogen, phosphoric acid, and potash in the feed consumed were determined by use of the average analyses¹ of the actual feeds consumed. As the descriptions and, wherever possible, the analyses, of the different feeds were recorded, it was possible to approximate quite closely the actual amount of fertility the manure contained. In this way all the nitrogen, phosphoric acid, and potash contained in all the feed consumed by each herd in the winter six months was computed. Of these fertilizing constituents 75 per cent of the nitrogen, 70 per cent of the phosphoric acid, and 85 per cent of the potash were taken as representing the amounts that would be voided in the manure. These proportions are based on the results of digestion trials conducted by the Illinois and Pennsylvania experiment stations.²

The amount of nitrogen which, it was calculated, was returned in the manure was about 5 per cent lower than the average of the results of the two experiments, because the cows on which records were kept were not, for the most part, fed so heavily as the experiment-station cows and would naturally retain more of the nitrogen in their bodies. The phosphoric acid allowed was practically an average of the experiments, and the potash was about 2 per cent more, as it was thought the Illinois cows, since the experiment was conducted in June, excreted considerable potash through their skins, which would not hold true to so great an extent for cows in the winter period.

When the total manurial constituents in the feed had been determined for each herd they were credited to the cows in accordance with the scores which had been given to the herds for the total manure saved. Each dairy was scored on its efficiency in saving manure, taking into account such factors as manure voided in the barn, quantity of liquid lost in the barn, and length of time and method of storing. The ingredients of the manure credited to each herd were

¹ Taken from "Feeds and Feeding," by Henry and Morrison.

² See Hopkins, Soil Fertility and Permanent Agriculture, pp. 201-202.

then added to the nitrogen, phosphoric acid, and potash contained in the bedding. The amounts of these constituents thus obtained constituted the entire fertilizer credit the cows received.

The composition of an average ton of manure produced by each herd in the winter period of each year was determined by dividing the fertilizing constituents it contained by the number of tons produced. It was possible to calculate the tons of manure produced for 100 pounds live weight of cows by using an average of the results of three experiments conducted by the New York station, and one by the Ohio station, on the amount of manure produced by dairy

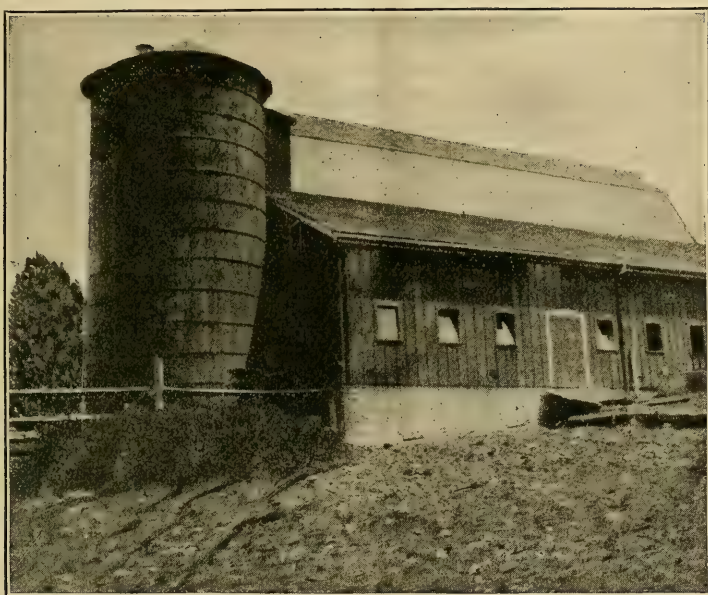


FIG. 8.—Brown streams which flowed from the exposed manure pile wasted dollars of fertility purchased in the feed.

cows.⁴ It was found by averaging these experiments that approximately 13 tons of manure were produced annually for 1,000 pounds live weight of cows. Our computations on tons of manure produced are based on this figure together with the weights of the cows on which records were kept. The bedding used was largely straw.

The fertilizing constituents contained in one average ton of the manure and bedding from all the cows on which records were kept in the two winters were found to be as follows:

	Pounds.
Nitrogen.....	9.8
Commercial phosphoric acid.....	3.2
Potash.....	10.1

⁴ Thorne, "Farm Manures," p. 97,

The average ton of manure, without bedding, produced by the cows in the winter months contained:

	Pounds.
Nitrogen	9.7
Commercial phosphoric acid.....	3.1
Potash.....	9.0

Since these amounts are based directly on the contents of the feed consumed and bedding used, they are fairly representative of the manure and bedding, and manure alone, from average dairy cows handled for market-milk production.

Table 14 summarizes the total costs represented by the feed, labor, and overhead and other charges, and the credits represented by the calves and manure:

TABLE 14.—*Proportion of total costs represented by feed, labor, and overhead and other costs.*

Cost factors.	Average of 2 winters.	Average of 2 summers.	Average of 2 years.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Feed cost.....	59.6	36.0	49.4
Pasture cost.....		19.0	8.2
Feed and pasture cost.....	59.6	55.0	57.6
Labor cost.....	19.1	20.1	19.5
Overhead and other costs except depreciation on cows.....	20.1	23.4	21.6
Total cost except depreciation on cows.....	98.8	98.5	98.7
Depreciation on cows.....	1.2	1.5	1.3
Total cost including depreciation on cows.....	100.0	100.0	100.0
Credits allowed for calves and manure:			
Calves.....	6.0	8.0	6.8
Manure.....	23.7	4.8	15.5
Calves and manure.....	29.7	12.8	22.3

The depreciation on the cows is reported separately from the overhead and other costs because there was such a wide variation in the figures representing this item for the two years. There was a depreciation on cows during the first year, which increased the cost of production approximately 6 per cent, but during the second year the total cost was reduced by about 3 per cent on account of an appreciation in their value, due in part to an increase in market prices for cows. It will be noticed also that the labor cost amounted to 19.1 and 20.1 per cent, respectively, for the winter and summer periods, while the overhead and other costs, including depreciation on cows, increased from 21.3 per cent in the winters to 24.9 per cent in the summers. This difference, however, was not caused by a variation in the overhead and other costs, but was a result of a lower charge in the summer periods than in the winters for labor and feed, including pasture, which were required to produce a certain amount of milk. These percentages are necessarily changeable, since

they depend directly on the relative cost of the various items which are required to produce milk. The same is true of the percentages given as representing the part of the total cost which was offset by the credits allowed for calves and manure. The percentages are influenced not only by the variation in costs, but also by the values allowed for calves and manure and the amount of manure credited to the herds.

PRESENTATION OF RESULTS BY MONTHS, SEASONS, AND YEARS.

The variation in the monthly feed cost during any one of the seasons in either year was not large. In most cases the variations, as shown in Tables 15 and 16, are no more than might naturally occur on account of local conditions, such as a fluctuation in the price of feed or weather conditions. The reason why the November feed cost of each year was lower than for the other winter months probably is that during that month some of the herds were allowed to run in the fields that had been in crops, in order that scattered feed might be kept from going to waste. Some of the dairymen were later than others in beginning to feed their regular full winter rations.

The cost of feed other than pasture fluctuates from month to month in the summer, and the same is true of the cost of pasture, but when these two costs are combined the variation in the total monthly feed and pasture cost is no more than occurred in the winter months. In distributing the pasture cost over the summer seasons the amount of grass furnished by the pastures each month was estimated and the total season's charge for pasture distributed accordingly. The following per cents were used for both years: May, 15 per cent; June, 33 per cent; July, 20 per cent; August, 10 per cent; September, 12 per cent; and October, 10 per cent. Since the records have been compiled it appears that these figures must have been fairly accurate, for wherever a heavy charge for pasture was made the amount of other feed consumed was comparatively small.

TABLE 15.—*Feed and labor requirements, by months, for producing milk during the winters of 1915-16 and 1916-17.*

WINTER 1915-16.

Month.	Cows.	Milk sold and used.	Income from milk sold and used.	Income per 100 pounds, less freight charge.	Concentrates fed.		Dry roughage fed.		Succulent roughage fed.		Total feed cost.	Labor.	
					Cost.	Quantity.	Cost.	Quantity.	Cost.	Quantity.		Total human.	Total horse.
		<i>Pounds.</i>				<i>Pounds.</i>		<i>Pounds.</i>		<i>Pounds.</i>		<i>Hours.</i>	<i>Hours.</i>
November.....	353	186,859	\$3,575.88	\$1.91	\$798.24	65,838	\$385.34	98,241	\$393.30	192,000	\$1,576.88	4,792.2	471.7
December.....	345	189,791	3,652.17	1.92	1,004.59	88,009	612.05	148,982	637.21	318,600	2,253.86	5,190.7	487.6
January.....	336	189,211	3,522.06	1.86	1,129.25	90,055	649.64	134,083	641.23	316,292	2,420.12	5,455.0	457.3
February.....	331	185,098	3,318.43	1.79	1,031.55	70,412	561.14	116,055	648.50	322,216	2,140.99	4,848.8	598.2
March.....	319	198,222	3,492.05	1.76	1,211.57	90,446	560.62	109,348	621.18	308,576	2,393.37	5,135.7	591.2
April.....	323	190,550	3,372.76	1.77	1,074.84	76,629	661.53	127,140	577.26	288,630	2,313.63	4,717.1	593.7
Total.....	335	1,139,731	20,933.35	1.84	6,149.84	481,399	3,430.33	733,849	3,518.68	1,746,314	13,098.85	37,099.5	3,109.7

WINTER 1916-17.

Month.	Cows.	Milk sold and used.	Income from milk sold and used.	Income per 100 pounds, less freight charge.	Concentrates fed.		Dry roughage fed.		Succulent roughage fed.		Total feed cost.	Labor.	
					Cost.	Quantity.	Cost.	Quantity.	Cost.	Quantity.		Total human.	Total horse.
		<i>Pounds.</i>				<i>Pounds.</i>		<i>Pounds.</i>		<i>Pounds.</i>		<i>Hours.</i>	<i>Hours.</i>
November.....	408	215,310	\$4,957.12	\$2.30	\$1,114.04	74,470	\$788.52	171,180	\$724.95	345,376	\$2,627.51	5,714.2	483.2
December.....	413	239,129	5,951.29	2.49	1,361.59	93,326	1,029.57	212,123	742.48	371,192	3,133.64	6,505.6	648.5
January.....	411	257,122	5,559.81	2.16	1,511.55	93,273	959.30	192,592	809.46	394,504	3,280.32	6,592.9	649.2
February.....	407	249,501	5,149.18	2.07	1,526.13	85,323	865.60	158,832	662.83	341,413	3,054.56	6,112.3	564.5
March.....	397	268,337	5,249.84	1.97	1,839.46	96,245	888.38	145,872	738.86	368,502	3,436.70	6,311.4	582.3
April.....	394	252,456	6,418.36	2.54	1,868.47	89,674	946.81	135,934	596.76	298,380	3,412.04	5,361.7	541.6
Total.....	405	1,479,948	33,295.60	2.25	9,221.25	529,311	5,448.18	1,016,533	4,275.34	2,119,367	18,944.77	36,598.1	3,469.3

TABLE 16.—*Feed and labor requirements, by months, for producing milk during the summers of 1915-16 and 1916-17.*
SUMMER 1915-16.

Month.	Cows.	Milk sold and used.	Income from milk sold and used.	Income per 100 pounds, less freight charge.	Concentrates fed.		Dry roughage fed.		Succulent roughage fed.		Total feed cost, other than pasture.	Pasture cost.	Total feed and pasture cost.	Labor.	
					Cost.	Quantity.	Cost.	Quantity.	Cost.	Quantity.				Total human.	Total horse.
		<i>Pounds.</i>				<i>Pounds.</i>		<i>Pounds.</i>		<i>Pounds.</i>				<i>Hours.</i>	<i>Hours.</i>
May.....	325	201,275	\$3,168.22	\$1.57	\$534.19	38,424	\$65.94	10,828	\$274.59	101,284	\$874.72	\$588.63	\$1,463.35	4,131.9	532.6
June.....	328	196,110	2,765.66	1.41	214.82	16,905	3.38	450	160.56	80,280	378.76	1,294.96	1,673.72	4,038.8	522.5
July.....	328	183,207	3,151.07	1.72	355.63	26,861	179.87	40,839	138.23	69,116	673.73	784.82	1,458.55	4,321.4	577.6
August.....	330	177,480	3,210.36	1.81	542.01	42,131	417.47	94,100	253.28	126,643	1,212.76	392.41	1,648.17	4,188.2	429.5
September.....	343	193,332	3,401.32	1.76	678.87	51,474	153.93	38,405	219.82	109,760	1,052.62	470.89	1,523.51	4,102.1	424.2
October.....	338	202,456	3,494.17	1.72	759.69	57,485	148.10	25,922	281.06	164,183	1,188.85	392.40	1,581.25	4,401.6	420.6
Total.....	332	1,153,860	19,190.80	1.66	3,085.21	232,880	908.69	210,544	1,327.54	651,276	5,381.44	3,924.11	9,305.55	25,184.0	2,907.0

SUMMER 1916-17.

May.....	394	259,484	\$5,388.83	\$2.08	\$1,138.69	50,679	\$466.13	70,086	\$306.09	153,053	\$1,910.91	\$553.12	\$2,464.03	5,135.8	404.2
June.....	398	244,188	4,332.79	1.77	527.80	23,147	53.85	6,980	101.00	50,500	682.85	1,216.88	1,899.53	4,482.5	367.8
July.....	402	231,737	5,274.33	2.28	698.60	32,023	403.93	65,986	209.95	104,976	1,312.48	737.46	2,049.94	4,667.2	422.9
August.....	401	193,551	4,745.30	2.45	714.01	32,304	736.23	114,066	149.96	74,975	1,600.20	368.73	1,968.93	4,622.2	402.1
September.....	410	202,537	3,750.51	1.85	873.07	60,928	406.32	96,268	456.39	210,557	1,735.78	442.49	2,178.27	5,063.0	428.8
October.....	412	211,101	4,543.05	2.15	1,058.83	66,144	618.28	119,927	510.14	255,079	2,187.25	368.72	2,555.97	5,479.1	472.1
Total.....	402.8	1,342,598	28,034.81	2.09	5,011.00	265,225	2,684.74	473,311	1,733.53	849,140	9,429.27	3,637.40	13,116.67	29,449.8	2,497.9

The "overhead and other costs" are not shown by months. Since they were prorated evenly over the months in each season, and since there was no definite fluctuation in the production of milk by months, these costs per 100 pounds would be approximately the same throughout the season. Table 17 does not include cost of feed and labor, but only the overhead and other costs which have not been previously itemized.

TABLE 17.—*Capital invested and overhead and other charges against buildings, equipment, and herds.*

Item.	Winters.	Summers.	Two years.	Per cent of inventory value.
Buildings:				<i>Per cent.</i>
Inventory.....	\$53,305.06	\$53,288.96	\$53,297.01	.....
Charges:				
Interest.....	1,332.64	1,332.24	2,664.88	5.0
Depreciation.....	1,105.77	1,105.43	2,211.20	4.1
Taxes.....	129.79	129.75	259.54	.5
Insurance.....	91.22	91.19	182.41	.3
Upkeep and repairs.....	386.71	386.60	773.31	1.5
Total charges.....	3,046.13	3,045.21	6,091.34	11.4
Equipment and supplies:				
Capital invested.....	10,546.18	10,546.18	10,546.18	.....
Charges:				
Interest.....	316.39	316.39	632.78	6.0
Taxes.....	5.76	5.76	11.52	.1
Depreciation.....	1,002.88	1,002.88	2,005.76	19.0
Repairs.....	87.17	87.17	174.34	} 2.6
Milking-machine repairs.....	49.45	49.45	98.90	
Total charges.....	1,461.65	1,461.65	2,923.30	27.7
Herds:				
Capital invested.....	62,975.00	62,975.00	62,975.00	.....
Charges:				
Interest.....	1,889.25	1,889.25	3,778.50	6.0
Depreciation.....	441.75	441.75	883.50	1.4
Taxes.....	289.76	289.76	579.52	.9
Insurance.....	97.18	97.18	194.36	.3
Total charges.....	2,717.94	2,717.94	5,435.88	8.6
Total overhead and other charges against buildings, equipment, and herds.....	7,225.72	7,224.80	14,450.52	11.4

SUMMARY.

In the production of market milk in those dairies under observation the various cost and credit factors, except cost of management, bore the following relation to the total cost of production: Feed and pasture, 57.6 per cent; labor, 19.5 per cent; overhead and other costs, 22.9 per cent. The total cost was offset 22.3 per cent by calves and manure.

The unit requirements for keeping a cow one year were: Concentrates, 1.02 tons; dry roughage, 1.65 tons; silage and other succulent roughage, 3.64 tons; hauling and grinding concentrates, \$1.53; bedding, 0.36 ton; pasture, 1.36 acres; human labor, 164.5

hours; horse labor, 16.2 hours; overhead and other costs, \$27.11. Credits other than milk: Manure, 6.8 tons; calves, 0.87.

Interest, depreciation, and similar items on buildings amounted to 11.4 per cent of their inventory value. Corresponding charges against equipment were 27.7 per cent of the equipment inventory, and the herd charges were 8.6 per cent of the herd inventory. The total charges against buildings, equipment, and livestock amounted to 11.4 per cent of their combined inventory value (see Table 17).

Men performed 84.7 per cent of the work about the dairy in winter, but in summer only 80.7 per cent of it. The rest of the labor was performed by women or boys and girls.

The net cost of producing 100 pounds of milk was 1.8 per cent higher from November to April, inclusive, than during the period of May to October, inclusive, and the total cost varied only slightly from month to month during any one season. A little more labor was required to produce 100 pounds of milk in the winters than in the summers.

There was no close correlation between the monthly cost of milk and the monthly price received for it during the two years.

The proportion of cows which freshened each season was uniform, and the calf crop was divided equally between the winter and the summer periods.

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UNITED STATES DEPARTMENT OF AGRICULTURE



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WM. A. TAYLOR, Chief



Washington, D. C.



September 7, 1920

THE PROCESS OF RIPENING IN THE TOMATO, CONSIDERED ESPECIALLY FROM THE COMMERCIAL STANDPOINT.¹

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SHIPMENTS OF EARLY TOMATOES TO NORTHERN MARKETS.

The shipping of tomatoes grown in Florida to northern markets during the winter and spring months is an exceedingly important industry. In Table I are presented statistics prepared by the Bureau of Crop Estimates and the Bureau of Markets of the United States Department of Agriculture, showing the production and car-lot shipments of the seven States where the early-tomato crop is chiefly grown.

From the figures shown in Table I it can be seen that Florida ships annually more than half of the total quantity of early tomatoes forwarded from the seven States specified. Statistics show that

¹ This bulletin gives the results of a portion of the work carried on under the project “Factors affecting the storage life of vegetables”. The paper was completed after the writer was transferred to the Office of Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations of the Bureau of Plant Industry.

The writer wishes to express his special indebtedness to Mr. Thomas J. Peters, of Miami, Fla., for providing facilities for the field work and for cooperating in other ways. He desires also to express his thanks and appreciation to Mr. H. H. Bartlett, of the botanical department of the University of Michigan, for counsel and suggestions during the progress of the work.

the industry in Florida is very largely concentrated in Dade and Broward Counties, at the southern tip of the State.

TABLE I.—*Production of early tomatoes in the principal producing States of the United States, showing also car-lot shipments, for the 5-year period from 1915 to 1919, inclusive.*

State.	Crop production (tons).					Car-lot shipments. ^a				
	1919	1918	1917	1916	1915	1919	1918	1917	1916	1915
California.....	17,380	11,880	17,390	20,170	18,750	139	1,513	518	1,169	871
Florida.....	58,520	46,800	77,480	101,170	91,390	4,478	3,695	4,493	6,184	4,692
Louisiana.....		600	1,810	2,209	2,524	2	10	14	58	58
Mississippi.....	18,400	21,150	15,680	25,250	20,100	61,388	61,379	61,063	61,663	61,690
Tennessee.....	6,000	10,500	13,020	29,320	24,010	366	654	947	590	529
Texas.....	17,700	16,000	16,430	10,770	11,260	1,198	1,123	1,276	1,153	1,318
Virginia.....		69,108	75,540	85,285	62,212		97	173	192	121
Total.....	118,000	176,038	217,350	274,174	230,246	7,571	8,471	8,484	11,009	9,279

^a Estimated at 13 tons per car except in Mississippi, where the average is 10½ tons per car.

^b Carloads of 10½ tons.

In spite of the fact that thousands of cars of Florida tomatoes are shipped to the North each year, the quality of a large percentage that reaches the consumer is admittedly inferior in many respects to vine-ripened or greenhouse tomatoes. Tracy (52) ¹ makes the following statements in regard to the inferiority of shipped fruit:

The tomato never acquires its full and most perfect flavor except when ripened on the vine and in full sunlight. Vine and sun ripened tomatoes, like tree-ripened peaches, are vastly better flavored than those artificially ripened. This is the chief reason why tomatoes grown in hothouses in the vicinity are so much superior to those shipped in from farther south.

It is the custom to pick the fruit when grass green and allow it to ripen and color in ripening rooms before shipment, while in transit, and after arrival at the market. Numerous complaints have been made by commission men and others that a large proportion of the tomato crop from the east coast of Florida is picked and shipped too green. When this is done, the fruit ripens very slowly, has a tendency to wrinkle, colors abnormally, and has a bad taste and flavor. Moreover, for quite different reasons, the growers prefer, when shipping their tomatoes, to have the fruit arrive in a slightly colored condition. The arrival of green fruit at the terminal often has the effect of glutting the market. The buyer is compelled to hold the fruit while ripening and consequently assumes a risk of losing a portion, whereas if the shipment is colored when it arrives he is able to dispose of it immediately.

Since the difficulties just enumerated bear a close relationship to field practice and to packing and shipping operations, the writer was stationed at Miami during the growing seasons from 1917 to 1919 in order to gain first-hand knowledge of the industry and to

¹ The serial numbers in parentheses refer to "Literature cited" at the end of this bulletin.

conduct experimental work with material grown under the conditions peculiar to Florida.

The quality of a tomato is largely determined by the amount and kind of sugars, plant acids, and vitamins which are present. It was obvious, therefore, that the method of approaching the problem would be a chemical one. If the chemical composition of vine-ripened tomatoes were known for a number of stages in the process of ripening, the data would afford a criterion for judging commercially ripened fruit.

GROWING AND HANDLING TOMATOES IN THE FIELD.

In the region about Miami, Fla., the seed beds are prepared as early as the middle of September and are planted at intervals until the early part of February in order to insure a steady supply of seedlings. In transplanting seedlings they are placed full length in the furrow, the roots are covered with a handful of moist well-rotted stable manure, and finally the whole stem, but not the leaves, is covered with loose soil. Commercial fertilizer is often used with the manure.

The soil upon which tomatoes are grown is essentially of an everglade type and is covered with water during a portion of the summer. For the past few years the moist soil and the danger of frost have been serious handicaps to very early planting. To insure a crop of tomatoes in case of frost many growers plant a portion of their fields in hills. The seeds are planted over stable manure and commercial fertilizer. After the seedlings appear the hills are thinned to one plant, which is allowed to grow to 6 inches or more in height and then bent down and covered with soil. The plants are 2 to 3 feet apart in rows 6 feet apart.

Commercial fertilizers are applied throughout the growing season up to picking time. Where only one side of the row is cultivated and the other allowed to grow in weeds, upon which the plants later lean, the fertilizer is applied in furrows on the side which is cultivated. About a week or 10 days after the plants are set out a small handful of the fertilizer is placed on one side of each plant. Sometimes it is covered with soil, but generally it is left uncovered. Ten days or two weeks after the first application, more fertilizer is applied between the plants in the original planting furrow. A shallow furrow is then turned to cover this fertilizer and also to support the plants better. The third application is placed in the furrow made when the second application was covered. The quantity is generally larger than the first and second applications and is covered by a new furrow. The fourth and final application is made in the same way. Where the fertilizer is applied at one side only, two rows are planted close together and between them weeds are allowed to grow. Where fertilizer is applied to both sides of the plants the

rows are 6 feet apart. The procedure is the same. The usual practice is to fertilize at the rate of 1 to $1\frac{1}{2}$ tons per acre, the last application being made several weeks before picking. The interval between applications varies with weather conditions and the growth of the plants. The custom is to locate the position of the rootlets along the side of the furrow made at the preceding application and to keep a quantity of fertilizer just ahead of these rootlets, so that a constant supply is available for the plant.

The time of picking the tomatoes of course depends upon the age and condition of the fruit. Many growers believe that it is an easy matter to determine the maturity by the character of the darkened area around the stem end. Toward the last stages of maturation the chlorophyll gradually disappears, especially around the stem end,



FIG. 1.—A tomato field in Florida.

where a whitened area is left. Fields are gone over once a week by the pickers, who collect the fruit in baskets or tin buckets. (Fig. 1.) In general the pickers (Nassau negroes) do not pay much attention to the color of the tomatoes, but gather those that appear large enough to ship. The tomatoes are dumped into field boxes at the ends of the rows and carried by wagon to the ripening house or packing house. The fruit is generally handled carefully, but often it is dropped from the gathering bucket to the field crate without the picker even bending over.

PACKING AND SHIPPING OPERATIONS.

Until recently the fruit was sorted, packed, and shipped immediately upon its arrival at the packing house, but the loss through disease and bruising was so great that it became necessary to adopt

the ripening house as a means of culling out undesirable fruit before shipping. In the ripening house the fruit is stored at a temperature of 75° to 85° F. for a variable period, depending upon the uniformity and maturity of the tomatoes at the time of picking. When most of them show a very slight red coloration they are removed and carefully sorted; all diseased fruits are discarded and the colored ones are graded, wrapped, and packed for shipment. Green fruit goes back to the ripening room. Improper conditions of ventilation, humidity, and temperature in the ripening room often increase the amount of disease, since such conditions favor the germination of fungous spores and the spread of infections brought from the field. Nevertheless, this method of allowing diseases to develop and then culling the fruit before shipping saves paying transportation charges on spoiled fruit, as well as additional loss in transit through the spreading of infection to healthy fruit.

The use of the ripening room is restricted to the early months of shipping, when the weather conditions are such as to allow the fruit to be shipped in a colored condition. The temperature is generally low enough to prevent too rapid ripening, and when the fruit reaches the North the temperature is still colder, thus allowing the fruit to be kept for a considerable length of time before it becomes too ripe. Later in the season, however, it is inadvisable with the present methods of handling to ship colored fruit. The tomatoes are kept in the ripening room for two or three days, to allow infections to develop, and are then sorted and shipped. In general, after warmer weather sets in the green fruit goes directly to the packing house from the field and is graded and shipped at once. Sometimes it ripens in transit, but more often it arrives green and has to be ripened at the terminal. Frequently the fruit is packed in such an immature state that it never attains its normal color. In such instances the grower loses both in reputation and in financial return.

When the tomatoes arrive at the packing shed they are dumped into bins, which usually are large enough to hold several crates. From these bins the grader culls all undesirable fruit and throws the good fruit into other bins, assorting according to size. Packers standing directly in front of the bins wrap the fruits individually in special tomato paper and pack them in 4-quart baskets. Each basket requires smaller fruit at the bottom layer than at the top, where the basket is wider, but in every basket the fruit is packed very tightly; in some cases quite a little squeezing is necessary. Six baskets are placed in each crate. The top is considerably bulged, owing to the close packing of the baskets. Crates in various stages of packing are shown in figure 2.

The method of packing crates for shipment just described is unfortunately the one generally used at the present time, but there is

another method that deserves careful consideration, in which the fruit after it is picked is washed and handled by means of a machine.

The field crates used in connection with the machine, and also by many growers who do not use a machine, are made of hardwood mill edgings that have been carefully planed and smoothed, especially where the tomato is likely to come in contact with them. The crate is open, so that all sand and dirt fall through and do not injure the tomatoes during hauling.

When the tomatoes arrive at the packing shed they are dumped into a large tank at the end of the machine, which contains a special washing solution kept at as high a temperature as the fruit will stand.



FIG. 2.—Scene in a Florida tomato packing house.

Were the solution with which the tomatoes are washed nothing more than hot water, it can hardly be doubted that the thorough removal of adhering sand, dirt, and fungous spores would be beneficial. The tomatoes remain in this supposedly disinfectant solution for about half a minute, constantly revolving, and are pushed toward an endless chain which carries them up an incline, where a spray of cold water rinses off the washing mixture. Drying is accomplished by passing the fruit between two layers of sponges. As it passes over the rollers, cullers are able to pick out the undesirable fruit without handling the remainder. It then passes over a special sizer, from which the several grades drop on tightly spread duck inclined planes

and roll down into pockets. The tomatoes are not jarred or bruised in any way in traveling from the tank to the packer.

Careful handling is essential in the successful production and shipping of tomatoes, and machine handling in the packing house is therefore to be highly recommended. Any device which will prevent bruising and cutting will reduce the opportunities for fungous infection and subsequent loss.

Refrigerator cars without ice are preferred by the growers for shipping, since these cars are fitted with ventilators which can be opened and closed as weather conditions require. Ventilated cars are used also when there is a shortage of refrigerator cars, but owing to their poor construction there is likelihood in the colder regions of the fruit freezing. When the cars first leave the South the custom is to have the ventilators open, but as they move farther north these are closed to prevent frost injury. When the cars are billed through to Canada some shippers close the ventilators as soon as the cars are filled. Each car contains an average of 500 crates, or approximately 13 tons of fruit. With so large a volume of respiring fruit in a confined space it is obvious that a condition of oxygen deficiency may easily come about.

PREVIOUS CHEMICAL INVESTIGATIONS OF THE TOMATO.

The earliest important chemical investigations of the tomato seem to have been those of J. F. John and C. Bertagnini, cited by Peckolt (37, p. 197). The latter author states that John probably made the first analysis of the tomato in 1814. Bertagnini, according to Palmeri (34), isolated citric acid from this fruit in 1850 and identified it by means of its silver salt.

In 1873, Kennedy (27) first isolated the alkaloid solanin from the tomato. His method was to macerate with dilute sulphuric acid for 48 hours. The expressed liquid was then treated with aqueous ammonia (sp. gr., 0.96) in excess. The precipitate which separated was filtered and dried at 120° F., after which it was extracted with hot alcohol. On cooling, the alcoholic solution deposited solanin as small feathery crystals.

The first quantitative analysis of the whole tomato fruit was that of Dahlen (16), who reported the amounts of water, protein, fat, glucose, crude fiber, ash, nitrogen, and phosphoric acid.

Since the work of Dahlen, various chemists have published analyses of the tomato. Palmeri (34) in 1885 reported on the constituents of various portions of the fruit and also included an ash analysis. Various later attempts were made to show the amounts of nitrogen, phosphoric acid, and potash which the tomato removed from the soil and also the effect of different fertilizer treatments on the composition of the fruit. The most important work along this line was

performed by Patterson (36), Bishop and Patterson (12), Voorhees (55), Alwood (3), Alwood and Bowman (4), Bailey and Lodeman (8), Bailey (7), and Jenkins and Britton (26).

There has been no little difference of opinion concerning the kind of acid occurring in the tomato. As before stated, Bertagnini (37) isolated and identified the acid as citric, while McElhenie (30) believed that oxalic, citric, and malic acids were present. Patterson (36) makes the following statement:

On following the schemes for the detection of organic acids as given in Fresenius's Qualitative Analysis, paragraph 193, page 342, and Prescott's Organic Analysis, page 336, the following acids were found to be present in the concentrated juice of the tomato, viz, malic, tartaric, benzoic, and formic. Malic acid predominated and the others appeared to be present in very small quantities, and as there has been no time for a further investigation as to the relative amounts of these, the whole of the free acids has been calculated as malic acid.

Passerini (35) claims that the acidity is due chiefly to citric acid and makes the statement: ¹

Il sapore dolce é dovuto a glucosi, i quali hanno azione risultante levogira sulla luce polarizzata; l'acidita per la massima parte ad acido citrico, come dimostrammo in altra nota.

Briosi and Gigli (13) also confirm the presence of citric acid: ²

Queste esperienze provano nel liquido giallo la presenza dell'acido citrico; e siccome isaggi con l'acqua di calce e col cloruro di calcio, ed altri che per brevità non riferiamo, escludono l'acido tartarico, possiamo credere che l'acidita stessa sia, almeno per la massima parte dovuta a esso acido citrico, già riconosciuto nel pomodoro per la prima volta da Bertagnini.

Alwood and Bowman (4) make the following statement:

A qualitative examination showed the presence of citric, malic, tartaric, formic, and succinic acids. Of these the citric acid was by far the most abundant, so that in the quantitative determinations the whole acid was calculated as citric acid.

Stüber (50) reports that apparently all the acid present was citric, and in no case was tartaric, malic, or succinic acid found.

Formenti and Scipiotti (19) claim that salicylic acid occurs naturally in the tomato to the extent of 15 to 25 milligrams per kilogram of fresh fruit juice.

Albahary (1) gives the following acids as occurring in the tomato: Malic, 0.48 per cent; citric, 0.09 per cent; oxalic, 0.001 per cent; tartaric and succinic, traces. He also reports the presence of an amino acid (2).

Bacon and Dunbar (6) state that—

the acid of tomatoes has been called by various authors malic, citric, tartaric, and oxalic. The acid is actually citric, as shown: * * *

¹ Translated as follows: The sweet taste is due to glucose, which has a resulting levorotatory action upon polarized light; the greatest part of the acidity is due to citric acid, as we have shown in a previous note.

² Translated as follows: These experiments prove the presence of citric acid in the yellow liquid; experiments with lime water and calcium chlorid and others which we do not mention for the sake of brevity exclude tartaric acid. We may believe that this same acidity is due, at least for the most part, to that citric acid already recognized in the tomato for the first time by Bertagnini.

Congdon (15) differs from Bacon and Dunbar (6) and claims that the acids are oxalic, citric, and a very slight amount of malic. Oxalic acid is supposed to predominate.

The preponderance of opinion seems to be that the chief acid in the tomato is citric.

With regard to the kind of sugar occurring in the tomato there is more uniformity of opinion. Patterson (36) says:

A few samples of tomatoes were examined for both classes of sugars, the glucose being determined in solutions made up without application of heat; and then a portion of this solution was made up in the usual manner for the cane-sugar determinations. The amount of increase indicating cane sugar was so small that it was thought to be probably due to substances of a gummy or pectose nature, which are well understood to form sugars which act on Fehling's solution when treated with mineral acids. And from the amount of free acid in the tomato, cane sugar would not be likely to exist to any extent.

Briosi and Gigli (13) believe that levulose is the sugar to which the sweetness of the yellow juice is chiefly due.

Alwood and Bowman (4) say that "it is very probable that no other sugars than those of the glucose kind exist in tomatoes."

Snyder (46), however, reports the presence of reducing and non-reducing sugars.

Stüber (50) finds no change in the sugar content of sugar samples before and after inversion.

Albahary (2) presents data showing the presence of cane sugar.

Bacon and Dunbar (6) make the following statement:

A number of experiments have shown that the sugar of tomatoes is usually invert sugar, with at times a slight excess of levulose.

Thompson and Whittier (51) were unable to find sucrose in either green or ripe fruits, but reported approximately equal quantities of levulose and dextrose, concluding that in the classification of fruits according to the kind of sugar present the tomato falls in the invert-sugar group. One of the more recent investigators, Bigelow (11), shows that sucrose is probably absent. He states:

It is probable that the sugar in tomatoes is all invert sugar. This was indicated by some samples which were examined, in which the determination of sugar before and after inversion gave the same results.

The work herein reported supports the contention of most scientific workers that little or no cane sugar is present in the tomato. It is very probable that where small amounts of sucrose are indicated by the increased reduction of Fehling's solution after acid hydrolysis that the increased reduction is due to other substances than invert sugar.

Since the data of the present investigation concern the percentage composition of the entire fruit, the comparable results of previous analyses of the whole tomato have been assembled in Table II.

TABLE II.—*Summary of the more important analyses of the whole tomato fruit.*

[An asterisk (*) indicates that the figure was obtained by the writer, using data given by the particular author. All others are original.]

Author and condition.	Variety.	Num- ber of deter- mina- tions.	Water.	Total solids.	Sugar- free solids.	H ₂ O solu- ble solids.	Re- ducing sugar.	Starch.	Crude fiber.	Total acidi- ty.	Total N.	Pro- tein.	N-free ex- tract.	Fat, etc.	Ash.	K ₂ O.	P ₂ O ₅ .
Dahlen (16):																	
Wet.....		1	92.87	*7.13	*4.60		α2.53		0.84		0.200	1.25	*4.07	0.33	0.633		0.081
Dry.....		1			*64.51		35.42		11.32		2.81	17.59	*57.09	4.64	8.89		1.14
Babcock (5):																	
Wet.....	Early Acme.	3	91.26	*8.74	*5.28		α3.46		.70	50.57	*.16	1.00	*5.84	.47	.73		
Dry.....	do.	3			*60.41		39.54		8.03	6.52	*1.33	11.25	*66.82	5.35	8.32		
Voorhes (55):																	
Wet.....	Best crossed.	12	94.00	6.00					.54		*.124	.78	3.78	.41	.49	0.258	.067
Dry.....	do.	12							9.0		*2.06	13.00	63.00	6.83	8.17	*4.30	*1.11
Patterson (36):																	
Wet.....	60 varieties	612	95.61	*4.39	*1.47	3.85	*2.92		.62	6.45	*.144	.90	2.07	.40	.40	.269	.046
Dry.....	do.	612			*33.48	*87.69	66.52		14.12	*10.25	*3.27	*20.50	*47.15	*.91	*9.11	*6.13	*1.05
Passerini (35): d																	
Wet.....	Nostrali.		93.02	*6.98			α3.73		11.07	9.815	h.165	h.1.03		f.696	f.728	h.432	.094
Dry.....	do.						53.50		15.33	11.68	1.83	14.79	9.97	9.97	.79	6.19	1.347
Wet.....	Napoleani.	5		6.39			*2.67			*3.61							
Dry.....		2	93.60	6.39													
Briosi and Gigli (13): m																	
Wet.....			*95.54	*4.46											12.36		
Dry.....																	
Alwood and Bowman (4):																	
Wet.....	Trophy.	2	93.34	*6.66													
Dry.....	do.	2							1.158		*.167	1.044	3.649	.469	.337		
			9	93.63	6.37				17.40		*2.51	15.68	54.80	7.05	5.07		
Common.		11				3.82	α2.09			n.71							
Bailey and Lodeman (8):																	
Wet.....	Ignofum.	8	*94.17	5.83	*.96		α4.87										
Dry.....	do.	8			16.49		*83.53			b.72							
Bailey (7):																	
Wet.....			p94.33	p5.67						.46							
Dry.....	do.						91.01			*8.30							
Caldwell (14):							*17.70										
Wet.....	do.						0.97			b.57							
Dry.....	do.		*94.33	α5.67	*4.44		*17.93			*10.05							
Handbook Exp. Sta. (53):																	
Wet.....			93.64	*6.36	*3.31		α3.05		.75	b.46	.16	n.91	α3.80	.43	.47	.27	.05
Dry.....					*52.64		*47.96		11.79	*7.23	*2.51	*15.72	*58.33	6.71	*7.39	*4.24	*.78

Relatively few investigations have been reported showing the progressive changes in composition of the tomato. Differences in composition between green and ripe fruit are given in several instances, but the researches of Albahary (2) and Bigelow (11) seem to be the only systematic studies of the changes occurring during development.

Passerini (35) reports a partial analysis of both green and ripe fruits of two varieties. The data, which are expressed in terms of wet weight, seem to indicate that as the tomato matures there is an increase in water and sugar and a decrease in total solids and acid. Formenti and Scipiotti (19) found that the water content of the entire fruit was greater in the ripe fruit than in that half ripe. Thompson and Whittier (51) reported a slightly larger percentage of total sugar in ripe than in green tomatoes.

Congdon (15) reported the specific gravity of ripe and green tomatoes as 1.0216 (average of eight) and 1.0230, respectively; also the citric acid content as 0.528 (average of eight) for ripe and 0.990 for green fruit. Bigelow (11) studied the composition of tomatoes (expressed juice) at different stages of maturity, but did not arrive at any very definite conclusions. He states that in general the percentage of solids and sugars increases and the percentage of acid decreases as the tomato becomes more mature.

Albahary (2) has given the most complete account of the chemical transformations in tomatoes during ripening. He used three successive stages of ripening: (1) Green fruit before seed development, (2) green fruit at the time seeds were completely formed, and (3) fruit which was fully ripe, and he concluded that with ripening there is a progressive increase in acids, sugars, starch, and nitrogenous nonprotein constituents, while proteins and cellulose diminish greatly, remaining practically stationary toward the end of ripening.

From the preceding résumé of former work on the chemical composition of the tomato at different stages of its growth, it is seen that there is little consistency in the results obtained.

The red pigment of the tomato is not estimated in any of the routine analyses. It has been isolated by several workers, who found that the amount recoverable was 0.2 per cent of the dry weight of the fruit or less. Its preparation in pure crystalline condition was first accomplished in 1876 by Millardet (31), who named it solanorubin. After it had passed into the synonymy of carotin, it was again isolated, in 1903, by Schunck (45), who renamed it lycopin. Montanari (32) made the first analysis and proved that it was a hydrocarbon. The final identification of lycopin as an isomer of carotin was made by Willstätter and Escher (58). In 1913 Duggar (17) studied the effect of conditions upon the development of the tomato pigmentation and found the color of the ripe fruit to depend (1) upon the presence or absence of lycopin in the flesh (in the absence of red lycopin the flesh is yellow, due to carotin and possibly xantho-

phyll, which are masked in the red fruit) and (2) upon the presence or absence in the epidermal walls of a yellow pigment. In the presence of the latter the red flesh is seen through a yellow screen, giving a more or less orange effect, but if it is absent the skin is transparent and the color a clear red.

EXPERIMENTAL MATERIAL.

The fruit for all the analytical work herein reported (with the exception of the "puffy" fruit discussed in the appendix) was obtained from plants of the Livingston Globe variety grown at Peters, Dade County, Fla. This variety is almost exclusively used for winter shipping to northern markets. For the life-history work the plants were grown in a field where the soil conditions represented the average of the entire acreage planted in tomatoes. These plants had the same treatment as the commercial plantings. They were set in the field in January and, following the local practice, were given four applications of commercial fertilizer and the usual quantities of compost.

In the former studies of the progressive changes in composition during ripening the tomatoes for sampling were classified by size and were usually picked at one time. This method of sampling was not deemed sufficiently accurate to be used in the present investigation, for ripe tomatoes have a great range of variation in size, which fact alone should enable one to conclude that it is not the size that determines the degree of maturity. In order to establish a basis for selecting fruits of comparable maturity, blossoms were tagged and observations made as to the time of ripening. In a series of observations made during the summer of 1918 at Arlington, Va., several hundred blossoms of Livingston Globe plants were tagged, and part of the fruit was picked every week, weighed, and measured. The important fact brought out by the experiment (Table III, Sec. A) is that the maturity of a tomato fruit depends upon age and not upon size. In the latitude of Washington, D. C. (at Arlington, Va.), 49 days were required to bring the fruit to maturity, starting with the blossom. Of the 20 fruits left upon the vines, all colored at the same time regardless of size or weight. The experiment was repeated with plants grown in Florida, and the same results were obtained. (Table III, Sec. B). In this case 200 tomatoes remained on the vines at the end of 56 days, 181 of which were colored (turning to red) and 19 green. The variations in size and weight were as great as at Arlington, if not greater. It was impossible to judge to the day the age of the blossoms which were tagged, but the variation among blossoms was hardly more than one or two days.

This method of obtaining tomatoes of known relative maturity is a fairly accurate procedure and is certainly to be preferred to that used by other investigators, who selected fruit according to size.

TABLE III.—*Weights and equatorial diameters of individual tomatoes grown at Arlington, Va., in the summer of 1918, and at Peters, Fla., in the winter of 1918, picked at intervals from blossoming time until the fruits were ripe.*

Locality and descriptive data.	Color of fruit.	Individual tomatoes.										Aver- age.
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	
SEC. A.—Arlington, Va.:												
Weight (grams)—												
Age 7 days.....	Green...	0.30	0.50	0.70	0.90	1.50	1.60	1.70	1.80	3.00	3.40	1.54
Age 13 days.....	do.....	1.40	2.00	3.60	5.30	6.10	13.90	14.60	17.50	20.80	21.60	10.68
Age 21 days.....	do.....	39.60	40.70	42.20	45.00	50.50	82.60	85.70	87.60	90.00	93.60	65.75
Age 30 days.....	do.....	52.90	57.10	71.50	79.80	83.40	109.50	114.30	115.70	128.60	135.40	94.82
Age 38 days.....	do.....	34.30	49.40	64.40	76.56	81.90	155.10	169.90	190.30	276.70	284.00	135.25
Age 49 days.....	Turning to red.	55.80	94.10	98.80	122.80	137.20	164.00	180.70	197.60	234.50	247.90	153.34
Diameter (cm.)—												
Age 7 days.....	Green...	.45	.60	.65	.80	1.05	1.10	1.15	1.15	1.40	1.55	1.14
Age 13 days.....	do.....	1.00	1.20	1.60	1.80	1.80	2.60	2.70	2.70	2.70	2.80	2.10
Age 21 days.....	do.....	3.80	3.80	3.90	4.00	4.10	4.80	4.90	4.90	4.90	5.00	4.41
Age 30 days.....	do.....	4.20	4.30	4.60	4.70	4.80	5.40	5.40	5.50	5.60	5.70	5.02
Age 38 days.....	do.....	3.80	4.10	4.40	4.80	4.90	6.00	6.10	6.40	6.70	7.30	5.45
Age 49 days.....	Turning to red.	4.60	4.90	5.20	5.40	5.70	5.90	6.30	6.70	6.90	7.30	5.49
SEC. B.—Peters, Fla.:												
Weight (grams)—												
Age 7 days.....	Green...	.07	.08	.08	.08	.09	.11	.52	.55	.67	1.13	.33
Age 15 days.....	do.....	1.68	1.75	1.84	2.27	2.32	9.40	10.63	11.95	12.39	13.19	6.74
Age 21 days.....	do.....	40.78	44.67	45.12	46.57	46.67	57.03	68.02	86.35	86.42	124.72	63.65
Age 28 days.....	do.....	43.79	62.60	63.53	67.12	69.18	75.35	77.48	91.85	111.97	160.84	82.37
Age 35 days.....	do.....	53.32	64.37	73.40	76.31	94.92	95.25	97.92	100.12	118.95	177.48	95.10
Age 42 days.....	do.....	78.60	95.45	95.82	99.81	100.78	126.66	151.23	195.36	222.11	313.33	147.91
Age 56 days.....	Turning to red.	79.18	110.18	127.72	131.52	139.97	157.42	170.54	179.69	185.18	346.79	162.81
Diameter (cm.)—												
Age 7 days.....	Green...	.43	.45	.45	.45	.45	.55	.85	.95	1.05	1.30	.69
Age 15 days.....	do.....	1.60	1.60	1.60	1.70	1.75	2.80	2.85	2.90	3.10	3.25	2.31
Age 21 days.....	do.....	4.50	4.55	4.60	4.60	4.65	4.85	5.65	5.80	6.00	6.60	5.18
Age 28 days.....	do.....	4.50	5.00	5.00	5.05	5.20	5.50	5.50	5.80	6.20	7.00	5.47
Age 35 days.....	do.....	4.45	4.70	4.75	5.15	5.45	5.45	5.60	6.05	6.15	7.00	5.47
Age 42 days.....	do.....	5.00	5.45	5.50	5.60	5.75	6.25	7.25	7.25	7.25	7.35	6.37
Age 56 days.....	Turning to red.	5.25	5.65	5.70	5.80	5.90	6.40	6.60	6.75	6.85	8.85	6.38

Plates I and II show in color four stages in ripening, which are referred to later in this bulletin as green, i. e., with no red present (*A*); turning, i. e., mostly green, with a trace of color at the style end (*B*); pink, i. e., slightly colored over most of the fruit, with little or no green except at the stem end, but not yet a good full red (*C*); and red ripe, i. e., completely mature as far as color change is concerned (*D*).

Material for analysis was obtained by tagging blossoms (other than those of the "crown hand")³ soon after opening and then collecting tomatoes at the different stages in numbers large enough for sampling. An attempt was made to pick all the tagged fruit from an entire row in order to eliminate the error that possibly otherwise might have occurred of unconsciously selecting large or small fruit. Samples were taken at the end of the second, third, fourth, fifth, and sixth weeks, and after the tomatoes had barely started to color (designated as turning), and finally when fully colored or ripe. At the time of carrying on the work the weather conditions were such that eight weeks were required to bring the tomato to maturity (red ripeness).

³ Growers are accustomed to refer to all the fruit developing from a single inflorescence as a "hand." The "crown hand" is the lowest inflorescence on the stem. It frequently fails to set fruit.



A



B

COLOR STAGES IN THE RIPENING OF THE TOMATO.

Green, *A*: turning, *B*.



C



D

METHODS OF ANALYSIS.

Sampling and preservation.—In order to obtain representative samples at each stage of ripening and to avoid the necessity of analyzing a large number of individual fruits to determine existing variations, composite samples were resorted to. These composite samples were taken from approximately 20 tomatoes. To eliminate error due to possible correlations between size and chemical composition, tomatoes were chosen so that each composite sample was obtained from fruits of all sizes, with the exception of abnormally large or small fruit which were discarded. The method of collecting the samples was uniform throughout. Where the fruits were small (e. g., those 14 days old) a 200-gram lot was made by using entire tomatoes, but with larger fruit samples of 200 grams were made up by removing a cylinder from each tomato with a half-inch cork borer. The cylinders were taken through the equator perpendicularly to the axis. A fairly representative sample was obtained in this manner, for the portion removed from each tomato was roughly proportional to the size of the whole fruit. The method of preserving samples for analysis was similar to that used by Hasselbring and Hawkins (21) in their studies of sweet potatoes and identical with the procedure of Kraus and Kraybill (28) with tomatoes. The material was heated with 80 per cent alcohol for 1 hour at 70° to 75° C., with the addition of calcium carbonate (CaCO_3) to insure the neutralization of acids. Two-quart glass-top jars were used, and approximately 1,065 c. c. of 95 per cent alcohol and 0.5 gram of precipitated CaCO_3 were added, after which the heating was carried out on a boiling water bath. Moisture and ash samples were merely covered with 95 per cent alcohol without subsequent heating.

In preparing the samples for analysis (with the exception of certain moisture, dry-weight, and ash samples) the alcohol was removed from the insoluble residue by filtering into a 2-liter volumetric flask. The residue was thoroughly extracted with warm 80 per cent alcohol, which was cooled, filtered, and added to the original filtrate. The volume of the flask was then made up to mark at 20° C. (referred to later as the original extract) and one-tenth and three-twentieths aliquots pipetted off and placed in separate Florence flasks, which were stoppered, labeled, and set aside. The residue was dried at 80° C. in an air oven for a few days and then allowed to come to air-dry weight, after which it was weighed and finely ground in a drug mill (referred to later as the original residue). One-tenth and three-twentieths portions were weighed and stored in small stoppered vials.

Moisture, dry weight, and ash.—An entire 200-gram sample covered with 95 per cent alcohol was placed in a large beaker and evaporated nearly to dryness on a steam bath. It was then transferred to a

250 cubic-centimeter tared beaker and dried at 60° to 70° C. to apparent dryness, after which it was dried in vacuo at 80° C. until the loss between two successive weighings was negligible. For ash the residue was ground in a mortar, then placed in the vacuum oven over night and approximately one-half of the total sample used for the crude-ash determination.

Acidity.—All acid determinations were made with fresh material. Two hundred grams of tomatoes were pulped and placed in a liter volumetric flask, made up to volume with cold distilled water, and toluol was added to prevent the growth of organisms. After standing three days, 50 c. c. aliquots were titrated against approximately a tenth normal sodium-hydroxid solution (N/10 NaOH), using phenolphthalein as the indicator. No trouble was experienced in determining the end point. Separate determinations were made until the duplicates checked. In order to determine the effect of enzymes on acid content, a sample treated with boiling water was titrated three days later and the results compared with one using cold water. For the former, 200 grams of material required 14.28 c. c. N/10 NaOH, and for the same quantity of material employing cold water, 14.18 c. c. N/10 NaOH were required for neutralization.

Free reducing substances.—One-tenth of the original alcoholic extract was evaporated nearly to dryness while the same part of the residue was being extracted on a filter paper with warm water (35° C.). Very little reducing substance remained after extracting the original residue with alcohol, as described under "Sampling and preservation," but the warm-water extraction was performed to insure the removal of final traces. The aqueous extract was combined with the residue from the alcoholic portion and filtered into a 250 c. c. volumetric flask, after which the filter paper was thoroughly washed. One cubic centimeter of lead-acetate solution (a saturated solution of the normal salt) was added and the solution made up to volume at 20° C. The whole was filtered immediately and the excess of lead removed by adding approximately 0.5 gram of sodium oxalate. After standing a short time the mixture was filtered through dry filter paper and 10 c. c. of the clear solution used for the sugar determination. The method used for determining reducing sugars was a combination of that of Bertrand (10), and that of Munson and Walker (33, 56). In this method the cuprous oxid is determined by titration, as in the Bertrand method, Fehling's solution and the time of heating are as specified by Munson and Walker. The Munson and Walker tables were used for the sugar equivalents.

Total sugars.—Fifty cubic centimeters of the solution used for free reducing sugars were transferred to a 100 c. c. volumetric flask and 5 c. c. of HCl (sp. gr., 1.19) added. The mixture was set aside over night and the flask made to volume at 20° C. the following morn-

ing. The solution was then neutralized and filtered and 20 c. c. used for reduction.

Starch.—The residue from the water extraction of the sample used for reducing substances was placed in an Erlenmeyer flask and heated immersed in a boiling water bath for $2\frac{1}{2}$ hours with 150 c. c. of water and 15 c. c. of HCl (sp. gr., 1.125). After cooling and neutralizing to phenolphthalein with NaOH, the mixture was made to 250 c. c. volume at 20° C. and filtered through a dry filter paper; 20 and 50 c. c. aliquots of this solution were used for reduction.

Pentosans.—A quantity of the original alcoholic extract representing one-tenth of the total extract was evaporated nearly to dryness in an Erlenmeyer flask and one-tenth of the original residue added to this. Pentosans were determined by the furfural-phloroglucid precipitate method. The usual procedure is to distill over 360 c. c. and then to make up to 400 c. c. with a phloroglucin solution. It required 480 c. c. of distillate to obtain all of the furfural present, and 40 c. c. of phloroglucin solution were added to this. No correction was made for the additional 120 c. c. distilled over. Kröber's formulæ were used in calculating the pentosan equivalents, as given in the Official and Provisional Methods of Analysis (57).

Total nitrogen.—Two hundred cubic centimeters of the original alcoholic extract, representing one-tenth of the sample, were introduced into a Kjeldahl flask and evaporated to dryness on the steam bath, and to this residue one-tenth of the original residue from the original sample was added. The total nitrogen in the aliquot was determined by the Kjeldahl method.¹

Crude fiber.—A quantity of the residue representing three-twentieths of the sample was used for crude-fiber determination, which was made in the usual manner.

ANALYTICAL DATA CONCERNING PROGRESSIVE CHANGES IN COMPOSITION DURING RIPENING.

The data showing progressive changes in composition during the process of ripening are assembled in Table IV. In section A of this table the percentages are referred to the weight of the entire fruit; in section B they are reduced to a basis of dry weight. Each entry in this table is a mean of two determinations, except as indicated by an asterisk (*), which shows that duplicate determinations were not made.

Although the method of sampling has been described, it may not be amiss to emphasize the fact that each sample was a composite of fruits of the same maturity but of greatly varying sizes. The data with regard to average size and average weight at the various ages are found in Table III.

¹ All determinations of nitrogen reported in this investigation were carried out by the Nitrogen Laboratory, Bureau of Chemistry, United States Department of Agriculture.

TABLE IV.—*Progressive changes in the composition of Livingston Globe tomatoes during the process of ripening.*

[The asterisk (*) indicates that the given result is based upon a single determination; results not thus marked are the mean of two determinations.]

Constituents.	Age and color of fruit.						
	14 days, green.	21 days, green.	28 days, green.	35 days, green.	42 days, green.	56 days, turning.	56 days, red.
SEC. A.—Percentage of entire fruit:							
Moisture.....	*93.250	*94.140	*94.140	*94.540	*94.240	*94.450	*94.490
Total solids.....	*6.750	*5.860	*5.860	*5.560	*5.760	*5.550	*5.510
Sugar-free solids.....	5.006	3.824	3.753	3.416	3.385	2.994	2.847
Ash, crude.....	*.634	*.562	*.533	*.509	*.497	*.484	*.504
Acidity (as citric acid).....	.320	.585	.352	.883	.640	.397	.420
Total nitrogen.....	.1999	.150	.1365	.1305	.140	.1225	.116
Protein (= N × 6.25).....	1.247	.938	.853	.8156	.875	.766	.725
Total sugar (as invert).....	1.743	2.006	2.106	2.143	2.375	2.556	2.667
Cane sugar.....	.018	.041	0	.018	.070	.018	.024
Reducing sugar (as invert).....	1.724	1.962	2.112	2.125	2.300	2.537	2.637
Starch.....	1.068	.830	.616	.544	.555	.222	.146
Pentosans.....	.332	.276	.247	.273	.264	.228	.238
Crude fiber.....	*.503	*.464	*.447	*.484	*.433	*.423	*.394
Ratio (sugar + acid).....	5.450	3.420	5.980	2.430	3.710	6.430	6.340
Carbohydrates—							
Total.....	3.647	3.576	3.415	3.443	3.628	3.429	3.441
Soluble.....	1.743	2.006	2.106	2.143	2.375	2.556	2.667
Insoluble.....	1.903	1.570	1.309	1.300	1.253	.873	.774
Determined constituents.....	99.100	99.801	99.294	100.192	99.870	99.526	99.580
SEC. B.—Percentage of dry matter:							
Sugar-free solids.....	74.120	65.250	64.050	61.440	58.760	53.940	51.670
Ash, crude.....	*9.390	*9.590	*9.090	*9.150	*8.620	*8.720	*9.140
Acidity (as citric acid).....	4.740	9.980	6.000	15.880	11.110	7.150	7.620
Total nitrogen.....	2.960	2.560	2.330	2.340	2.440	2.200	2.100
Protein (= N × 6.25).....	18.500	16.000	14.550	14.660	15.250	13.780	13.130
Total sugar (as invert).....	25.830	34.240	35.930	38.550	42.230	46.030	48.320
Cane sugar.....	.264	.708	0	.323	1.215	.324	.435
Reducing sugar (as invert).....	25.560	33.490	36.040	38.200	39.930	45.710	47.850
Starch.....	15.840	14.220	10.500	9.770	9.630	4.000	2.650
Pentosans.....	4.920	4.700	4.210	4.890	4.580	4.120	4.320
Crude fiber.....	*7.450	*7.920	*7.630	*8.710	*7.510	*7.620	*7.150
Ratio (sugar + acid).....	5.450	3.420	5.980	2.430	3.710	6.430	6.340
Carbohydrates—							
Total.....	54.030	61.030	58.270	61.920	63.970	61.720	62.450
Soluble.....	25.830	34.240	35.930	38.550	42.230	46.030	48.320
Insoluble.....	28.200	26.790	22.340	23.370	21.740	15.690	14.130

From Table IV it may be seen that the tomato contains a comparatively small amount of solid matter and that a considerable portion of this consists of acids and sugars, especially in the ripe fruit. In fruit 14 days old there are relatively small percentages of acids and sugars, but as the tomato matures these increase perceptibly in the case of acids and markedly in the case of sugars. In general, throughout the ripening period there is an increase in moisture, acids, and sugars and a decrease in solids, total nitrogen, starch, pentosans, crude fiber, and ash. Some of these losses are probably not absolute, but attributable to changes in the proportion of the constituents. Tracing the figures for moisture content from the first column, concerning tomatoes 14 days old, across to the last column for ripe fruit, it will be seen that there is a gradual and progressive increase in total moisture. The only irregularity is that noticed in the fourth column (for 35 days). The moisture content here is greater than it should be if the change followed a regular curve of increasing water, being greater than in fruit when fully ripe.

It seems that a clue to the reason for this irregularity is afforded by Table V, showing weather conditions for the period previous to picking the samples. Just before picking this particular sample there was a rainfall of 9.10 inches within 36 hours. This precipitation was as unusual for the locality as it was injurious. Not only was the actual rainfall excessive, but the overflow from the Everglades still further complicated the situation. In some places a total loss resulted, and everywhere some damage was reported. At Peters, Fla., where the fruit for this investigation was grown, the loss was comparatively small, but the ground was saturated for more than a week. In view of the fact that the only anomalous moisture content was found in the 35-day fruit, it seems justifiable to correlate it with the excessive rainfall. It would hardly be warranted, however, to conclude from this one instance that the moisture content is higher after a heavy rain than normally. The coincidence is merely pointed out and should be of some interest in view of the widespread opinion in the canning industry that a heavy rainfall increases the amount of water in tomatoes. Bigelow (11) was recently unable to draw any definite conclusions with regard to this matter.

TABLE V.—*Weight and equatorial diameter of tomatoes at dates when samples were taken, together with mean temperature and total precipitation for the period (usually seven days) preceding sampling.*

Time of sampling.	Color of fruit.	Average weight (grams).	Average diameter (cm.).	Meteorological data.	
				Temperature (° F.).	Precipitation (inches).
Age 14 days.....	Green.....	6.74	2.31	66	0.83
Age 21 days.....	do.....	63.65	5.18	73	.24
Age 28 days.....	do.....	82.37	5.47	77	.01
Age 35 days.....	do.....	95.10	5.47	62	9.42
Age 42 days.....	do.....	147.91	6.37	68	.27
Age 56 days.....	Turning to red.....	162.81	6.38	76	.09
Mean.....	.....	.....	.....	70	.....
Total.....	.....	.....	.....	.....	10.85

Inversely with moisture, total solids show a gradual decrease as the tomato matures. Turning to section B of Table IV, which gives the same data as those of section A of the same table, but reduced to a dry-weight basis, the sugar-free solids are seen to decrease considerably, while soluble carbohydrates increase and insoluble carbohydrates decrease regularly. Total carbohydrates vary somewhat, but in general seem to show an increase.

Regarding the changes in acidity, there is considerable fluctuation, but when we consider the changes in a general way there is an increase in quantity from the second week to the fifth and then a gradual decrease during the last three weeks of ripening. The total quantity of acid found in the red-ripe fruit is, however, still greater than in

the first stage analyzed. The possibility should be borne in mind that the ripe tomato may contain relatively more acid salts and less free acid than the green fruit. Since the acid content was determined throughout by titration to neutrality, with phenolphthalein as the indicator, it is obvious that the presence of acid salts might cause the analytical results to show more acid than the taste would indicate. As will be seen later, the change in the ratio of acid to sugar is in the direction to account for the sweetening that takes

place during ripening. Nevertheless it is not impossible that the ratio of free-acid salts is likewise of importance.

It is believed that rainfall and other factors influence the quantity of acid in tomatoes, although there are few analytical data at hand to indicate this. In the fourth column of figures of Table IV (sec. B), concerning the tomatoes that received the highest rainfall, the acidity is 15.88 per cent, and in the fifth column, where the tomato would no doubt be still affected, there is a decrease to 11.11 per cent, but this figure is higher than the remaining ones.

In this connection

it may be worth while to suggest that a tomato with excessive water content may have the intercellular spaces sufficiently diminished so that gas exchange is impeded. Under such conditions a deficiency of oxygen might result in an accumulation of acid, due to incomplete oxidation of carbohydrates to carbon dioxide.

The most striking change during ripening is that undergone by carbohydrates. In the first stage analyzed it was noticed particularly that insoluble carbohydrates composed 52.1 per cent of the

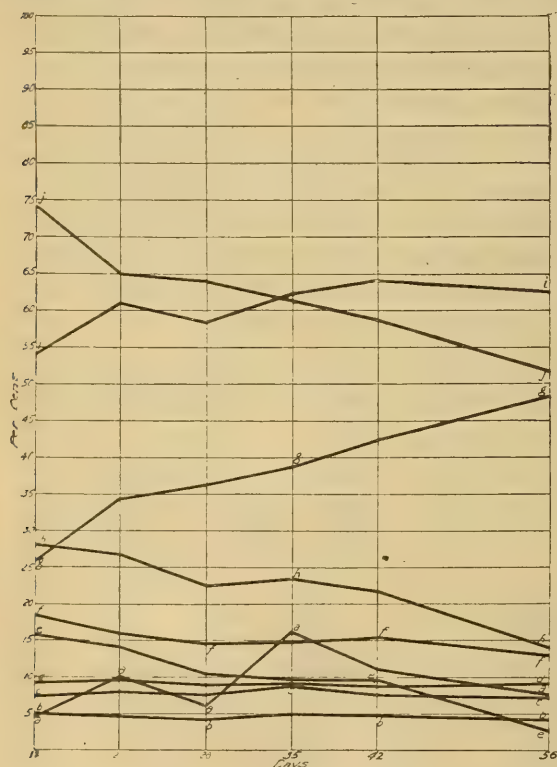


FIG. 3.—Diagram showing the progressive changes in the composition of Livingston Globe tomatoes during ripening. The percentages are based upon dry weight. Curve a-a, acid; b-b, pentosans; c-c, crude fiber; d-d, crude ash; e-e, starch; f-f, protein; g-g, soluble carbohydrates (total sugar); h-h, insoluble carbohydrates; i-i, total carbohydrates; j-j, sugar-free solids.

total carbohydrates present, while in the last stage, that of ripe fruit, soluble carbohydrates were in excess, amounting to 77.3 per cent of the total. Nearly all of the total sugar in the tomato fruit is apparently invert sugar, and this increases from 25.56 per cent in the case of 14-day-old fruit to 48.32 per cent in ripe fruit, an increase of nearly 89 per cent. Starch decreases during maturation from 15.84 to 2.65 per cent. The most marked decrease, as would be expected, is noticed during the period of transition from green to red. The progressive decrease in starch during ripening is in striking contrast to the increase in starch noticed by Albahary (2).

Pentosans decrease during ripening, but only to a comparatively slight extent.

Total nitrogen decreases gradually during ripening and this fact is rather interesting and important in the light of some recent investigations of Kraus and Kraybill (28). They make the following statements:

On account of the wide differences in composition of different parts of any plant grown under a given set of conditions, only similar portions are compared. With but few exceptions, increased amounts of total nitrogen are associated with decreased amounts of total carbohydrates. This condition holds fairly uniformly throughout the plant with the exception of the lower leaves.

Examination of Table IV (sec. B) shows that increased total nitrogen in the tomato fruit under the conditions used for the material in this investigation is associated with decreased total carbohydrates. The above investigators analyzed leaves and stems of the tomato plant, while the data presented in the present paper furnish analytical figures for the fruit, thus yielding complete analyses of the entire plant. The correlation between total nitrogen and total carbohydrates holds with respect to the fruit as well as to the other parts of the plant (excluding the lower leaves).

All of the changes during ripening are represented in the diagram shown as figure 3.

COMPARISON OF THE COMPOSITION OF COMMERCIALY PICKED TOMATOES WITH TURNING AND VINE-RIPENED FRUIT.

It is conceded by many commission men and by some of the growers themselves that the tomatoes shipped to the North differ very noticeably in flavor and palatability from normal fruit. The chemical composition of Florida-grown tomatoes compares favorably with the various analyses reported of such fruit grown in other localities, so the inferiority of the former can not be attributed to the kind of soil or climatic conditions prevailing in Florida. Elimination of these possibilities led the writer to look for other causes of the trouble. It will be seen from the analytical data which follow that tomatoes picked green and allowed to ripen exposed to air and light differ

slightly in composition from vine-ripened fruit. They contain more sugar-free solids, slightly more acid, and less total sugar than vine-ripened tomatoes, but these differences hardly explain the great difference in taste. In tracing the trouble to lack of ventilation it is believed that a proper explanation is presented. The analytical data upon which these conclusions are based are presented in Tables VI and VII.

TABLE VI.—*Composition of artificially ripened and vine-ripened Livingston Globe tomatoes.*

[The asterisk (*) indicates that the given result is based upon a single determination; results not thus marked are the mean of two determinations.]

Constituents.	Commercially picked; green.		Turning fruit.		Vine- ripened fruit; red ripe.
	As picked.	Ripened at room tempera- ture.	As picked.	Ripened at room tempera- ture.	
Sec. A.—Percentage of entire fruit:					
Moisture.....	*93.800	*94.310	*94.450	*94.540	*94.490
Total solids.....	*6.200	*5.690	*5.550	*5.460	*5.510
Sugar-free solids.....	3.975	3.059	2.994	2.916	2.847
Acidity (as citric acid).....	.508	.475	.397	.375	.420
Total nitrogen.....	.138	.1335	.1225	.1265	.116
Protein (= N × 6.25).....	.831	.834	.766	.791	.725
Total sugar (as invert).....	2.225	2.631	2.556	2.543	2.667
Cane sugar.....	.060	.012	.018	.024	.024
Reducing sugar (as invert).....	2.175	2.628	2.537	2.518	2.637
Starch.....	*.855	.095	.222	.101	.146
Pentosans.....	.258	.214	.227	.251	.238
Crude fiber.....	*.404	*.462	*.423	*.438	*.394
Ratio (sugar ÷ acid).....	4.380	5.540	6.430	6.780	6.340
Carbohydrates—					
Total.....	3.742	3.403	3.429	3.334	3.441
Soluble.....	2.225	2.631	2.556	2.543	2.667
Insoluble.....	1.517	.772	.873	.791	.774
Sec. B.—Percentage of dry matter:					
Sugar-free solids.....	64.110	53.770	53.940	53.410	51.670
Acidity (as citric acid).....	8.190	8.340	7.150	6.860	7.620
Total nitrogen.....	2.140	2.340	2.200	2.320	2.100
Protein (= N × 6.25).....	14.370	14.630	13.780	14.500	13.130
Total sugar (as invert).....	35.880	46.230	46.030	46.580	48.320
Cane sugar.....	.821	.210	.324	.430	.435
Reducing sugar (as invert).....	34.970	46.010	45.710	46.120	47.850
Starch.....	*13.790	1.680	4.000	1.850	2.650
Pentosans.....	4.170	3.770	4.120	4.600	4.320
Crude fiber.....	*6.520	*8.120	*7.620	*8.020	*7.150
Ratio (sugar ÷ acid).....	4.380	5.540	6.430	6.780	6.340
Carbohydrates—					
Total.....	60.870	59.800	61.720	61.050	62.450
Soluble.....	35.880	46.230	46.030	46.580	48.320
Insoluble.....	24.990	13.670	15.690	14.470	14.130

The percentage composition of samples of commercially picked green fruit (Pl. I, *A*), of the same after being ripened at room temperature, of turning fruit as picked (Pl. I, *B*) and after being ripened, and of vine-ripened fruit (Pl. II, *C*) is given in Table VI. All the fruit for the different samples was collected at the same time, in order that a comparison might be made. In the case of commercially picked green tomatoes, four crates were taken at random in one of the largest packing houses of the South. The fruit had just been picked and brought into the packing shed. The sample for analysis

was taken from as representative a lot as could be obtained, portions of approximately 20 tomatoes being used. These had been ripened by exposure to air and light in the laboratory until they assumed a characteristic ripe appearance, as judged by the color. They were sampled 13 days later. Turning tomatoes were taken to the laboratory after being picked and one lot sampled; another lot was set aside to ripen. Four days later they showed a red color and were therefore sampled. Vine-ripened fruit was, of course, sampled as soon as it was brought into the laboratory. Table VI summarizes the analytical results obtained. Comparing the analyses of commercially picked green tomatoes with those given in Table IV, it will be seen that green fruits are not mature, for the chemical transformations of ripening have not been completed. The sugar-free solids are comparatively high, while the sugars are correspondingly low. The total amount of carbohydrates is still low compared with that in mature fruit. Taking composition as a criterion of maturity, one must conclude that commercially picked green fruits are immature and therefore inferior. When green fruit is commercially ripened, however, changes take place, which, although corresponding in general trend to those of normal vine ripening, nevertheless fail to bring the fruit to the same degree of ripeness attained normally. The artificially ripened tomato is lower in total sugar than vine-ripened fruit (46.23 per cent of the dry weight in the former, as contrasted with 48.32 per cent in the latter) and higher in acid (8.34 per cent, as contrasted with 7.62 per cent). The ratio of sugar to acid in the former is 5.54, while in the latter it is 6.34. In other words, the artificially ripened fruit is different in taste, due to the lack of one constituent and an excess of the other. In spite of these differences, however, the taste is not as bad as that of fruit which reaches the market. If some way could be devised to place on the market fruit having substantially the same flavor as that found in tomatoes ripened like the samples used, there would be little likelihood of complaint.

When the data for turning tomatoes (Table VI) are examined, it is found that they compare more favorably with vine-ripened mature fruit than the commercially picked green fruits. In the interval between the time when green tomatoes are picked in commercial practice and the time of turning red on the plant, sugar-free solids normally decrease considerably, while sugars increase in proportion. Since in turning tomatoes there is very little starch present which can be converted into sugar, it is seen that there is not so marked an increase of soluble carbohydrates in further ripening as in the artificial ripening of green-picked fruit. The acid content changed from 7.15 to 6.86 per cent during ripening, but the latter figure is below that of normal fruit. The total amount of sugar is also below normal, but not as much so as in artificially ripened green tomatoes. The ratio

in the case of ripened turnings is 6.78, compared with 6.34 in vine-ripened fruit. This signified that the former should be comparatively sweet and less pronouncedly acid, as was indeed true. The facts brought out indicate that there is less chemical difference between turning and vine-ripened fruit than there is between commercially ripened green fruits and the latter. Differences in chemical composition between vine-ripened fruit and commercially picked green tomatoes ripened in the laboratory, exposed to air and light, are not sufficient to account for the marked differences in flavor and palatability between commercially ripened fruit and normal fruit. This conclusion was confirmed by taste comparisons.

EFFECT OF LACK OF VENTILATION ON RIPENING.

Since the differences due to ripening after picking with normal exposure to the air were obviously insufficient to account for the inferiority of Florida tomatoes after shipment, it seemed to be clearly indicated that the cause of the difficulty might well be lack of ventilation during commercial ripening. As already stated, the fruits are wrapped before packing for shipment, and it seemed not unlikely that the paper used might appreciably retard gas exchange and thus modify the course of ripening.

In order to test the hypothesis that wrapping plays an important part in influencing the composition and flavor of tomatoes, it was deemed necessary to analyze tomatoes which were ripened in a non-ventilated chamber and to compare the results with those obtained with wrapped fruit. Comparisons were made between (1) tomatoes commercially picked and ripened without ventilation, (2) commercially picked and ripened, wrapped with one paper, (3) commercially picked and wrapped with three papers, (4) commercially picked and ripened unwrapped at room temperature, (5) turnings ripened unwrapped at room temperature, and (6) vine-ripened fruit. All of the fruit used for the above comparisons was obtained at the same time. A box for the green fruit ripened with no ventilation was made of composition board about a quarter of an inch thick. The approximate size was a little less than 1 cubic yard. All corners were sealed with adhesive tape and the door was made by cutting it from the board and hinging it on. The total exclusion of air from the interior of the chamber of course was not secured, but the degree of nonventilation obtained was complete enough for the experiment, as shown by the fact that at times the oxygen content of the chamber would not support an alcohol flame. Six baskets of tomatoes (approximately 125 fruits) were allowed to remain in this chamber, which was heated with one electric bulb, until they showed a red color. They were then removed and sampled by taking portions from 15 to 20 fruits. It required 11 days for the color to appear. Other fruits

were wrapped with one and three papers and set aside at room temperature until they also attained a red color. These were sampled 11 days later. Summaries of the analyses are given in Table VII.

TABLE VII.—*Composition of commercially picked green Livingston Globe tomatoes allowed to ripen under different conditions as compared with artificially ripened turnings and vine-ripened red fruits.*

[The asterisk (*) indicates that the given result is based upon a single determination; results not thus marked are the mean of two determinations.]

Constituents.	Commercially picked; ripening—				Turning fruit; ripened at room temperature.	Vine-ripened fruit; red ripe.
	No ven-tilation.	One pa-per wrap-ping.	Three pa-per wrap-pings.	At room tempera-ture.		
SEC. A.—Percentage of entire fruit:						
Moisture.....	*93.930	*94.500	*94.430	*94.310	*94.540	*94.490
Total solids.....	*6.070	*5.500	*5.570	*5.690	*5.460	*5.510
Sugar-free solids.....	3.745	3.037	3.039	3.059	2.916	2.847
Acidity (as citric acid).....	1.104	.850	.673	.475	.375	.420
Total nitrogen.....	*.134	.131	.1265	.1335	.1265	.116
Protein (= N × 6.25).....	*.838	.818	.791	.834	.791	.725
Total sugar (as invert).....	2.325	2.462	2.581	2.631	2.543	2.667
Cane sugar.....	.048	.012	.077	.012	.024	.024
Reducing sugar (as invert).....	2.275	2.450	2.450	2.628	2.518	2.637
Starch.....	.079	.084	.139	.095	.101	.146
Pentosans.....	.255	.224	.238	.214	.251	.238
Crude fiber.....	*.482	*.482	*.473	*.462	*.438	*.394
Ratio (sugar ÷ acid).....	2.110	3.010	3.760	5.540	6.780	6.340
Carbohydrates—						
Total.....	3.140	3.253	3.381	3.403	3.334	3.441
Soluble.....	2.325	2.463	2.531	2.631	2.543	2.667
Insoluble.....	.815	.790	.850	.772	.791	.774
SEC. B.—Percentage of dry matter:						
Sugar-free solids.....	61.700	55.050	54.550	53.770	53.410	51.670
Acidity (as citric acid).....	18.180	15.450	12.080	8.340	6.860	7.620
Total nitrogen.....	*2.210	2.380	2.270	2.340	2.320	2.100
Protein (= N × 6.25).....	*13.810	14.670	14.190	14.630	14.500	13.130
Total sugar (as invert).....	38.290	45.950	45.440	46.230	46.580	48.130
Cane sugar.....	.791	.218	1.382	.210	.430	.435
Reducing sugar (as invert).....	37.450	44.540	43.980	46.010	46.120	47.850
Starch.....	1.301	1.620	2.500	1.680	1.850	2.650
Pentosans.....	4.190	4.080	4.270	3.770	4.600	4.320
Crude fiber.....	*7.940	*8.760	*8.490	*8.120	*8.020	*7.150
Ratio (sugar ÷ acid).....	2.110	3.010	3.760	5.540	6.780	6.340
Carbohydrates—						
Total.....	51.730	60.400	60.700	59.800	61.050	62.450
Soluble.....	38.290	45.950	45.440	46.230	46.580	48.320
Insoluble.....	13.440	14.450	15.260	13.670	14.470	14.130

There are striking differences in the analyses between the acid and carbohydrate content of tomatoes commercially picked and ripened without ventilation and the same fruit ripened when exposed to the air. Without ventilation the acids are very high and the soluble carbohydrates (sugars) are low. These facts indicate incomplete oxidation of carbohydrates to carbon dioxide (CO₂) with the consequent accumulation of acid. The connection of these changes in composition with the flavor is very obvious. The nonventilated fruit was markedly inferior. Although the reaction was decidedly acid, the general flavor was insipid. While the same effect was not produced to as great an extent in fruit ripened when wrapped with paper, it nevertheless takes place. Fruit wrapped with one paper had a noticeably inferior flavor; it was not as poor as the sample ripened without ventilation, but it was worse than that of green

fruit ripened without wrapping. The acid content of fruit ripened without ventilation shows an increase of approximately 138 per cent over that of vine-ripened fruit; that of fruit ripened while wrapped with one paper, an increase of approximately 102 per cent; and that of fruit ripened while wrapped with three papers, an increase of about 58 per cent. The soluble carbohydrate content for fruit ripened without ventilation shows a decrease of nearly 21 per cent compared with normal fruit; that of fruit ripened while wrapped with one paper, a decrease of nearly 5 per cent; and that of fruit ripened while wrapped with three papers, a decrease of nearly 6 per cent.

The data presented also bring out the fact that green tomatoes ripened when exposed to air and unwrapped are superior in taste and chemical composition to the same fruit ripened when wrapped with paper.

Several experiments were carried out in order to determine what effect lack of ventilation produced on the normal color of the tomato. Since they all yielded the same results, it will suffice to present the figures from one. Two large glass jars were filled with green fruit and cardboard covers placed over each. Unwrapped fruits were placed in baskets as checks. Both lots were held at room temperature and examined at the same time. (Table VIII.)

TABLE VIII.—*Effect of lack of ventilation on the normal coloring of tomatoes held at room temperature.*

Time of examination.	21 fruits in bottles (no ventilation).		31 fruits in baskets (ventilated).				
	Green.	Turning.	Green.	Colored.			
				Turning.	Pink.	Red.	Total.
After 6 days.....	21	.....	6	10	6	9	25
After 12 days.....	.....	21	.....	.....	5	a 26	31

a 14 soft.

These results would seem to indicate that lack of ventilation retards ripening and the consequent formation of pigment in the tomato. It was noticed that the tomatoes kept in jars were firmer than those left exposed to the air. Hill (24) records a similar condition in the case of peaches held in an atmosphere of carbon dioxid (CO_2). His explanation is that CO_2 evidently prevents the hydrolysis of the pectin to which peaches owe their hardness. This may also be the case with tomatoes. An attempt was made to duplicate the results presented above by using a larger closed chamber and also by wrapping the fruit in paper, but no concordant data were obtained. There are hardly sufficient data to justify making any statement as to the effect of wrapping on the color formation. It is often noticed that tomatoes picked green and ripened arti-

ficially acquire a much better color than vine-ripened fruit. The color is deeper and more even.

Investigation has been made by Duggar (17) of the effect of various conditions on the development of the tomato pigment (called by this author lycopersicin). He studied the effect of light and temperature on its development and concluded that high color is independent of any direct effect of light and that fruit will redden perfectly in darkness at a temperature of even 20° to 25° C. He also states that "when half-grown varieties are employed a temperature of 30° C. is sufficient to suppress lycopersicin development to a marked extent. Fruits nearer maturity, that is, those showing a blush of color, permit a stronger lycopersicin development at all temperatures employed." Duggar (17) also studied the relation of oxygen to pigment production in the tomato and concluded that lack of oxygen inhibited lycopersicin development.

From a consideration of all the data it appears that wrapping is harmful to the tomato and that lack of ventilation is probably the main cause of inferiority in taste and keeping quality.

In 1913 Hill (24) reported on the respiration of fruits and growing plant tissues in certain gases with reference to ventilation and fruit storage. He found that apples and peaches ripened poorly when oxygen was withheld from them. It was also pointed out that an accumulation of carbon dioxid within paper wrappers in which peaches are shipped and an insufficient supply of oxygen cause "ice scald."

Fischer and Nelson (18) recently came to a similar conclusion with regard to wrapping cantaloupes, maintaining that "wrapped cantaloupes do not refrigerate so well in transit nor do they reach the consumer in as good condition as do cantaloupes not wrapped." In both of these investigations similar conditions were found to be the result of wrapping, namely, that wrapped fruits were firmer but of poorer quality than those unwrapped.

Another serious disadvantage of the present method of picking and shipping green tomatoes lies in the fact that it is practically impossible to determine comparable stages of maturity in picking. In spite of the fact that the fruit of individual baskets is all approximately of the same size, the coloring of the fruit does not occur at the same time. The explanation for this fact has already been given. The maturity of a tomato depends on its age and not on its size; consequently fruits of the same size do not necessarily ripen and turn red simultaneously. The most obvious disadvantage of the inability to determine comparable stages of maturity is the fact that when the fruit does ripen, either in transit or after reaching the market, it colors up so irregularly that many sortings become necessary before the dealer is able to dispose of it. The more uniform in size and color a package is the more salable it is, so naturally the dealer sorts the fruit to insure

a quick sale. In consequence of many handlings the fruit becomes soft and injured and is more liable to fungous attacks through the germination of adhering spores. It is clear that, if possible, only fruit of the same age should be packed in a single container. No criterion for determining age exists except at the time of turning from green to pink. If turning tomatoes could be packed instead of green ones, this particular commercial difficulty would be solved. Since it has been shown, moreover, that Florida tomatoes are lacking in certain fundamental qualities as to taste, which would likewise be remedied by picking more mature fruit, the writer turned his attention to determining the feasibility of shipping "turnings." It was found, as would of course be expected, that the riper the tomatoes the shorter the time it is possible to hold them, but the fact was ascertained that "turnings" can be kept in good condition at a temperature approximating that obtained in refrigerator cars (50° to 55° F.) long enough to ship them and to sell them to the consumer. Turning tomatoes held in the refrigerator for 10 days and then kept at a temperature of approximately 75° F. for 5 days longer were found to be in an excellent condition. Other fruits remaining at the lower temperature for 15 days were still firm enough to be held at room temperature for a few days. At lower temperatures than those used it is possible to hold tomatoes even longer than 15 days. Iced shipments in pony refrigerators sent by express from Miami, Fla., to Washington, D. C., arrived in excellent condition. One commission man who has been shipping fruit under ice for a number of years states that these tomatoes reach the market in excellent condition and bring higher prices than uniced fruit. The above statements are not offered as recommendations for picking and shipping turning tomatoes under ice. There are, however, many good reasons for suggesting that turning fruit may be picked and shipped under an initial icing. One of these reasons has already been mentioned, namely, that it would be possible to pick fruit at the same stage of maturity which would ripen uniformly and save considerable of the loss which is at present experienced. Furthermore, chemical analysis has shown that turning fruit compares favorably with normal or vine-ripened fruit in composition, taste, and palatability. Other investigators, Powell (38), Ramsey (39, 40, 41), Stevens and Wilcox (47, 48), Ridley (42), and others, have shown that fruits are more liable to fungous infection when they are wounded than when uninjured. This is what one would expect in the light of some recent investigations which show a high correlation between susceptibility to infection and the resistance offered by the fruit to mechanical puncture.

The investigations of Rosenbaum (43) on the origin and spread of tomato fruit rots in transit have demonstrated that overripeness, bruises, and other injuries favor the appearance of these rots. Since the resistance of the epidermis shows the relative ease with which a fruit may become infected by means of a mechanical entrance of the

spore tube, tables are presented showing these data in connection with tomatoes. Table IX (sec. A) shows the pressure necessary to penetrate the epidermis of fruit of different ages. The epidermis of colored fruit is softer than that of green tomatoes 38 days old, yet the difference is too small to justify the conclusion that green fruits are preferable on this account. Table IX (sec. B) also shows the effect of temperature on the resistance of the epidermis to wounding. These results indicate that tomatoes are less liable to injury when cooled than when they are warm and consequently are less liable to fungous infection. It is generally known also that respiration decreases considerably with the lowering of temperature. The products causing the inferior taste and flavor in tomatoes probably result from intramolecular respiration as a result of withholding free oxygen from the tissues. Under the present methods of shipping tomatoes from the South it would be impossible to allow cars to remain open throughout the entire journey. The initial icing of cars at the warm end of the trip would have the effect of preventing the harmful result of lack of ventilation by reducing respiration to a minimum.

TABLE IX.—*Effect of age and temperature upon the resistance to wounding of the epidermis of Livingston Globe tomatoes, showing also color conditions.*¹

Descriptive data.	Sec. A.—Age of tomatoes. With needle having a diameter of 68 microns.						Sec. B.—Temperature effects. With needle having a diameter of—			
	7 days; green.	13 days; green.	21 days; green.	30 days; green.	38 days; green.	49 days; turning.	68 microns; turning.		78 microns; red ripe.	
Temperature of penetration (°C.).....	30	29	29	30	33	30.5	24	9	25	14
Average of 10 scale readings at which penetration occurred for individual tomatoes:										
No. 1.....	41.3	38.3	23.6	14.4	32.4	33.8	23.91	15.75	32.48	30.92
No. 2.....	40.9	36.3	27.8	23.2	33.3	31.6	32.81	28.54	30.87	31.21
No. 3.....	38.4	37.1	32.6	21.3	28.2	29.5	21.40	16.70	32.16	28.64
No. 4.....	40.6	37.3	33.9	20.4	24.8	30.7	22.97	18.66	26.36	24.65
No. 5.....	41.2	40.3	32.1	23.7	30.5	32.0	25.35	20.60	28.91	22.63
No. 6.....	41.0	40.3	31.5	24.8	32.6	32.6	27.38	23.54	27.95	27.84
No. 7.....	39.6	36.6	29.3	24.9	25.8	32.3	25.38	23.36	31.32	29.32
No. 8.....	41.3	37.6	34.7	25.6	18.6	26.1	18.47	16.27	31.86	29.42
No. 9.....	41.7	36.6	31.5	25.1	32.2	37.0	24.35	20.38	23.66	23.79
No. 10.....	41.9	37.5	34.2	25.5	30.5	30.2	27.80	25.08	26.61	28.46
No. 11.....	.....	39.8	32.1	27.7	27.5	32.6	29.19	25.72	.....	.....
No. 12.....	.....	39.3	30.5	25.0	28.8	30.5	.....	.....	.....	.....
No. 13.....	.....	37.4	26.3	21.6	30.0	29.1	.....	.....	.....	.....
No. 14.....	.....	37.1	31.3	28.1	31.5	30.1	.....	.....	.....	.....
No. 15.....	.....	38.8	22.6	25.4	33.9	28.7	.....	.....	.....	.....
No. 16.....	.....	36.8	29.8	25.6	30.4	.....	.....	.....	.....	.....
No. 17.....	.....	38.4	29.5	.....	27.8	.....	.....	.....	.....	.....
No. 18.....	.....	39.3	32.3	.....	.....	.....	.....	.....	.....	.....
No. 19.....	.....	39.5	24.9	.....	.....	.....	.....	.....	.....	.....
No. 20.....	.....	36.4	28.9	.....	.....	.....	.....	.....	.....	.....
Average scale reading for entire lot of fruit.....	40.8	38.0	30.5	23.8	29.3	31.1	25.35	21.33	29.32	27.6
Due to tension of spring, grams.....	11.75	10.86	8.49	6.38	8.11	8.67	13.20	11.80	6.96	6.46
Weight of needle and rod... do... ..	14.63	14.63	14.63	14.63	18.91	18.91	23.48	23.48	12.04	12.04
Pressure necessary to puncture... ..grams.....	2.88	3.77	6.14	8.25	10.80	10.24	10.28	11.68	5.08	5.58

¹ For detailed information as to the apparatus and methods used to obtain the data presented in this table, see the following references: Hawkins and Harvey (22); Hawkins and Sando (23); Rosenbaum and Sando (44).

Against the arguments in favor of picking and shipping turning fruit one must consider the advantages of present practices. The picking of turning fruit would require that the fields be gone over more frequently than at present and that the pickers exercise much more judgment and care. The writer had planned to make commercial shipments of tomatoes picked at the turning stage in order to get dependable information which might serve as a basis for recommending to the growers changes in the current practice, but the discontinuance of this work for the present has prevented the carrying out of the plan. It is of very great importance to the growers that these shipments be made. It is felt that the work reported upon in this bulletin supports the chemical explanation offered of the inferiority of tomatoes shipped from the east coast of Florida during the winter and spring months. It remains to be determined whether the changes in current practice suggested in these pages can be put into effect. If they can be, the result of these investigations will be to insure the consumer a better product in the future than in the past.

SUMMARY AND CONCLUSIONS.

With the particular object of discovering the chemical basis for the inferiority of commercially picked and ripened Florida tomatoes marketed in the North during the winter and spring, a series of analyses has been made of tomatoes of several degrees of maturity and of tomatoes ripened artificially under various conditions of ventilation.

It was found that the only way to secure samples of comparable maturity for analysis was to tag the blossoms and pick the fruit at a definite age. There is a wide range of variation in the size of the tomatoes within the same variety, but ripening proceeds at a uniform rate regardless of size. Maturity is dependent upon age, not upon size.

Using fruit of known age, therefore, analyses were made which indicate that in general throughout the ripening period there is an increase in moisture, acids, and sugars and a decrease in solids, total nitrogen, starch, pentosans, crude fiber, and ash.

The most striking change which occurs during ripening is that undergone by carbohydrates. Sugars increase from 25.66 per cent in fruit 14 days old to 48.32 per cent in ripe fruit.

Starch decreases in the same interval from 15.84 to 2.65 per cent. The most marked decrease takes place during the period of transition from green to red.

The percentage composition of fruit picked green but ripened with free access of air compared with analyses of turning and vine-ripened fruit did not show enough variation to account for the great differ-

ences in taste found in commercially shipped fruit. Turning tomatoes showed less difference from vine-ripened fruit than did the green fruit and compared favorably with normal tomatoes not only in composition but also in taste.

The effect of lack of ventilation on ripening was to increase the acid content approximately 138 per cent over that of vine-ripened fruit. The flavor of tomatoes ripened without ventilation was very inferior. The soluble carbohydrate content showed a decrease of nearly 21 per cent. Commercially ripened green fruit, wrapped with one paper, showed an increase in acid of approximately 102 per cent and a sugar decrease of nearly 5 per cent compared with corresponding tests of vine-ripened tomatoes. The results of wrapping with three papers were less marked and are difficult to explain.

The data seem to justify the conclusion that wrapping probably modifies the course of ripening to such an extent as to account for marked changes in taste and flavor. The combined results of picking fruit green, of wrapping, and of closing the cars in transit probably account for the total differences existing in quality between commercially shipped and vine-ripened tomatoes.

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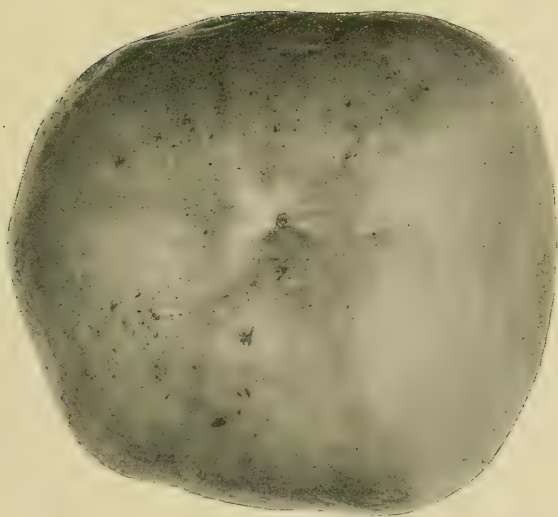
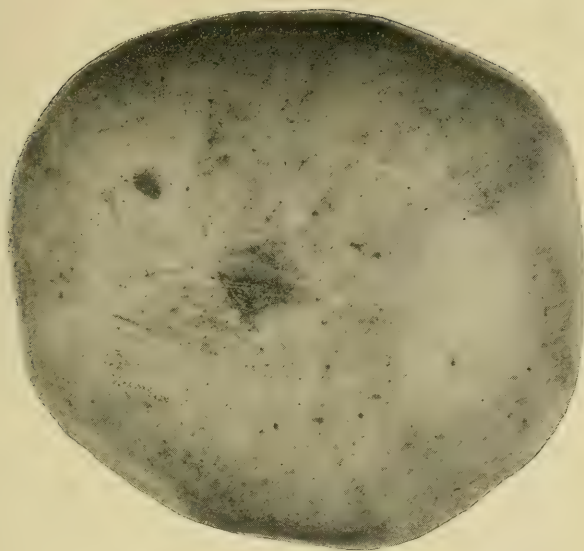
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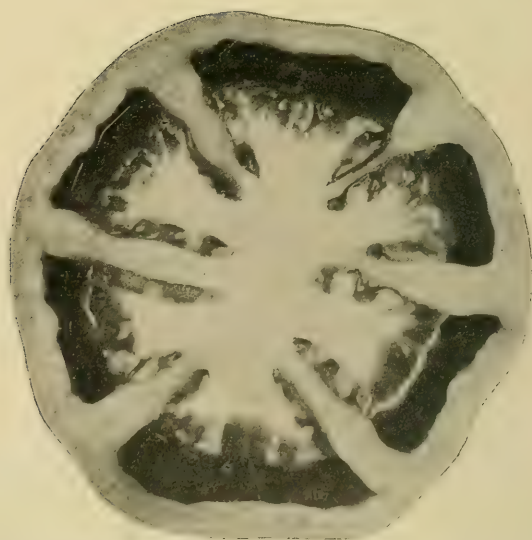
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EXTERIOR OF A NORMAL AND OF A "PUFFY" TOMATO.



INTERIOR OF A NORMAL AND OF A "PUFFY" TOMATO.

APPENDIX.

COMPARISON OF THE COMPOSITION OF "PUFFY" AND NORMAL LIVINGSTON GLOBE TOMATOES.

The abnormality in tomatoes called puffiness is one in which the seed cavities are affected. The fruit sounds hollow when it is patted with the hand and shows external angular irregularities. Plates III and IV show the angular appearance of the exterior and also the characteristic appearance of the interior of the fruit. In a locality where the trouble was especially pronounced one crate of tomatoes was taken at random from a packing house and the number of hollow and normal fruits estimated. The figures follow: Estimated by the sound before cutting, normal 58, hollow 95; estimated by cutting the fruit in two, normal 32, partly hollow 56, pronouncedly hollow 66.

Counts were made in order to determine whether certain plants produced fruits that were all hollow and other plants produced normal fruit. It appears that a single plant may produce both normal and hollow fruit. There is no stage in the life history of the tomato at which puffiness is a natural occurrence, but it may occur on small as well as large fruit. It does not seem to affect the amount of color or the time of ripening. Table X shows that although there are some differences in chemical composition between normal and "puffy" fruit there are no possible explanations to be gained from this standpoint.

Various fertilizer plats were arranged to determine the effect of different amounts of nitrogen, potash, and phosphoric acid upon the production of "puffy" fruit. Seven plats were set out and the fertilizer mixtures were given in four applications at the rate of 1 ton to the acre. The fertilizer ingredients consisted of acid phosphate, sodium nitrate, and potassium sulphate, and the following ratios were used on the various plats: 1 : 5 : 3; 1 : 10 : 8; 3 : 5 : 3; 3 : 10 : 8; 3 : 6 : 0; 7 : 5 : 3; and 7 : 10 : 8.

TABLE X.—Composition of normal and "puffy" Livingston Globe tomatoes. Both samples picked green, but fairly mature.

Constituents.	Normal fruit.		"Puffy" fruit.	
	Wet basis.	Dry basis.	Wet basis.	Dry basis.
Moisture.....	94.36	-----	94.32	-----
Total solids.....	5.64	-----	5.68	-----
Sugar-free solids.....	2.93	51.95	2.84	50.00
Total nitrogen.....	.140	2.48	.139	2.45
Total sugar (as invert).....	2.71	48.05	2.84	50.00
Reducing sugar (as invert).....	2.40	42.55	2.61	45.95
Starch.....	.42	7.44	.38	6.70
Alcohol-soluble pentosans.....	.034	.602	.033	.581
Insoluble pentosans.....	.190	3.54	.197	3.47
Crude fiber.....	.55	9.75	.54	9.51
Carbohydrates:				
Total.....	3.904	69.38	3.990	70.26
Soluble.....	2.71	48.55	2.84	50.00
Insoluble.....	1.19	20.83	1.15	20.26

Examination of the fruit produced in this experiment showed that both normal and hollow fruits were to be found on every plat. Complete counts could not be made, owing to the destruction of the vines by a flood before the end of the season, but enough observations were made to show that within the limits used varying quantities of fertilizer elements did not influence the production of hollow fruit.

No positive results were obtained in this study showing the cause of puffiness in tomatoes, but the evidence indicated that the condition is not correlated with any considerable differences in the chemical composition of the mature fruit. The phenomenon is probably physiological in its nature, for the same varieties which show it in Florida are said not to do so, or only to a very slight extent, when grown in Michigan. A great difference that immediately occurs to one between conditions in the two places is that in Florida the crop is produced only through heavy annual applications of commercial fertilizers, which are not used in Michigan. Puffiness may therefore be dependent upon an unbalanced soil solution, but, if so, none of the variations in the fertilizers just enumerated sufficed to restore a proper condition. It is, of course, not inconceivable that puffiness is of a genetical nature and due to somatic variation. If so, it might, in conformity with the observed facts, be much more frequent in some varieties than in others, and the same plant might show both normal and "puffy" fruit. The whole subject is one which needs investigation.

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GEORGE LIVINGSTON, Chief



Washington, D. C.

August 20, 1920

THE ORGANIZATION OF COOPERATIVE GRAIN
ELEVATOR COMPANIES.

By J. M. MEHL, *Investigator in Cooperative Organization*, and O. B. JESNESS,
Specialist in Cooperative Organization.

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INTRODUCTION.

This bulletin is primarily intended to furnish a plan of organization and method of procedure for persons required to assist in the formation of cooperative grain elevator companies. It should be of interest to producers contemplating organization, to ordinary private corporation types of farmers' elevators desiring to reorganize on the cooperative plan, and to persons interested in cooperative organization in general. While it has been prepared with special reference to conditions existing in the grain States, it is not intended to meet the particular requirements and conditions which are peculiar to any one State. Its scope is limited to matters which are regarded as fundamental and general, and the suggestions and recommendations made are to be considered with reference to and in connection with

special cooperative laws and the laws governing corporations in each of the several States.

The success of any organization, whether cooperative or for private profit, will be found to rest upon: (1) Social or economic need; (2) a sound organization plan; and (3) efficient management. The lack of any one of these fundamentals impairs the whole.

A cooperative elevator company, like any other business organization, must rest first upon some substantial economic need. An organization may come into existence by means of propaganda and enthusiasm engendered to serve a political, fraternal, or idealistic purpose, but unless some substantial benefit or service is secured to the community such organization eventually must fail. The value to the community of any enterprise or undertaking is measured in direct proportion to the need therefor.

The plan of organization must be sound. This means that something more is necessary than mere statements of the high purposes and aim of the association. It means a definite and practicable plan of action, a plan which anticipates so far as it is possible to anticipate the practical problems and difficulties to be met in actual operations.

A cooperative enterprise in order to be successful must be conducted under efficient management and in accordance with a well-defined business policy. There has been too much tendency in the past to employ as managers men who are merely industrious and honest and who may not have that keen, discriminating judgment and tactful address so necessary in managerial positions.

FORMS OF ORGANIZATION.

In the United States three distinct forms of farmers' elevator organizations are found, namely, (1) joint stock companies and unincorporated societies; (2) ordinary private corporations of the capital-stock form; and (3) cooperative associations incorporated under special cooperative law.

JOINT STOCK COMPANIES.

The advantages of the joint stock company form of organization consist mainly in—

(1) The ease of effecting organization, no formal procedure being necessary.

(2) The saving of fees connected with incorporating.

(3) Exemption from certain taxes affecting corporations.

(4) Relief from the necessity of filing numerous corporate reports sometimes required of corporations.

The joint stock company is adapted principally to small and compact organizations which desire to utilize some of the features of

corporations and still retain a partnership relation between the members. For organizations made up of a large number of members each having a comparatively small financial interest it is neither a convenient nor a desirable form, and for that reason it has not gained general favor in the farmers' elevator field.

Some of the disadvantages of this form are:

(1) Each individual member of the company usually is jointly and severally liable for the entire company obligations.

(2) The company can sue only in the names of the individual members composing it or in the name of a person first duly empowered, and if it is made defendant in a suit only those members served with process are held.

(3) The company can not take, hold, or convey real estate by its company name, and every encumbrance or deed of conveyance must be executed in the names of the individual members, or by some person first authorized to act as their agent.

The grain business is attended with some hazard, no matter how well conducted, and few men are willing to assume the partnership liability which usually follows the joint stock company form of organization.

ORDINARY PRIVATE CORPORATIONS.

The corporation-for-profit form of organization has predominance in number at the present time, although there is a decided tendency to reorganize under recently enacted State cooperative laws. During the period when the farmers' elevator movement had its most rapid development the ordinary corporation-for-profit form was about the only possible corporate form of organization and it was adopted from necessity rather than from choice. Comparatively few corporations were organized which did not attempt with by-law provisions to secure some of the cooperative features specially authorized by later statutory enactment. Among these were the one-man, one-vote principle; limitations upon share ownership; and, to some extent, but not generally, the patronage refund and restricted dividend on capital stock, which now are considered the backbone of a really cooperative company. Considering that many of these features were without legal license and that they depended for effect entirely upon the mutual consent of the members, it is remarkable that the corporation-for-profit form has endured so well. However, the difficulties usually do not develop until the membership character begins to change, through the retirement of members from active farm life, and the interests of stockholders become those of investors rather than of producers.

A large majority of the 4,000 or more farmers' elevator companies in the United States have at the time of organization been coopera-

tive in purpose, if not in form or effect. Of the whole number perhaps one-third now are cooperative in the sense that earnings over and above operating expenses and a reasonable rate of interest on capital are distributed on the basis of patronage furnished. It is this feature of patronage refund and limitation of dividends upon capital stock to an interest charge which slowly but surely is establishing a class of farmers' elevators that are properly designated as cooperative. The term "farmers' elevator" is properly applied to all forms of elevator organizations owned and controlled in the main by farmers, but it is doubtful whether the term "cooperative elevator" will long be considered applicable to those organizations which have not adopted the patronage dividend or refund system in the distribution of earnings.

THE COOPERATIVE FORM.

The form of organization which under existing conditions and law will most effectively promote and protect the fundamental and now generally recognized cooperative principles is the form in which farmers' elevator organizations are interested. For shipping associations which do not buy outright the products of their members and which act only in the capacity of selling agent, the nonstock form¹ is perhaps best suited to conserve cooperative principles. In the case of farmers' elevators, however, which require considerable fixed capital, and which buy and sell grain and other products and supplies on a profit above cost basis, it is doubtful whether anything but a capital stock form of organization can be employed to advantage at present. Most of the grain States now have cooperative laws which authorize patronage dividends and other cooperative features. These laws are not uniform in all of the States, nor do they meet every requirement, but organization under them offers the best form at present, and will secure the benefits of any future amendments and changes in the law which are not inconsistent with present provisions. Among the cooperative principles not yet provided for in the cooperative laws of some of the States the following may be mentioned:

(1) Limitation of voting power to one vote per member, regardless of the number of shares or the amount of capital stock owned.

(2) Limitations upon the number of shares or amount of capital stock that any single member may own.

(3) Restrictions upon the power to sell or dispose of shares of stock except to persons acceptable for membership in the association.

It may be that in states where each stockholder is entitled to one vote for each share of stock owned, what amounts to a one-man, one-vote rule may be secured by issuing only one share of stock to each

¹ For description see U. S. Department of Agriculture Bulletin 541, Cooperative Organization By-laws, by C. E. Bassett and O. B. Jesness, 1918.

member but providing different classes of stock with shares of varying par value. Some of the desirable cooperative features which are not especially authorized by the laws under which an organization is incorporated and which might not be valid as a by-law provision alone, may possibly be secured by means of a contract arrangement made at the time of issuing the stock certificate. Any and all by-law provisions in regard to which there is any doubt should be made the subject of a special contract by having them printed upon the stock certificates. This will also have the effect of giving notice of the restrictions to possible purchasers.

MAKING PRELIMINARY SURVEY.

Before the organization of a cooperative elevator company is attempted or advised, a careful and unprejudiced survey of local conditions should be made in order to determine the economic need for the organization and to secure information that will be of assistance when the work of actual organization is undertaken later.

LOCAL CONDITIONS.

First it will be desirable to study the conditions under which grain is generally marketed in the particular local community in which organization is contemplated. Whether or not that community normally is devoted to feeding or to shipping is of importance in this connection. The fact that marketing facilities are grossly inadequate one year does not necessarily indicate that other and additional facilities can be supported advantageously during a series of years. A fair comparison should be made between prices paid by local dealers and prices obtaining in the principal terminal markets, with due reference to freight and other charges deductible therefrom. It must not be imagined, however, that every daily newspaper can at all times be relied upon to report terminal values fully and accurately. It frequently occurs that even if such values are quoted accurately, there are coexisting conditions under which the prices are not available to the local buyer, and therefore are not applicable to current purchases in the country. In making a study of local marketing conditions it will be desirable to secure the services and advice of some practical grain man. If available, the advice of managers of successful neighboring associations will be especially valuable.

Information regarding the amount of grain shipped from any station during a period of several years should be obtained from local representatives of railroads, from the general offices of such railroads, or from State commissioners or bodies having charge of transportation matters within the State. Having determined the average volume of grain shipped from a certain station annually, its division among already existing agencies and dealers should be

considered. The volume of business which any single elevator is able to control will largely determine the minimum margin per bushel that is required to meet the overhead and operating expenses. The operating cost per bushel necessarily must be greater in handling 100,000 bushels per year than it would be in handling 200,000 bushels per year. This applies with particular force to elevators dealing in grain exclusively. Of course, elevators which look to an extensive merchandise business for their main source of income may handle a small volume of grain with very little additional cost. Not infrequently such operators use their grain business as a feeder to their more profitable merchandise business, in which case competing elevators, handling grain exclusively, are placed at a decided disadvantage.

Although the community need for cooperative marketing can not always be judged from the number of existing commercial agencies, for cooperative marketing may be made necessary at times by reason of having too many such agencies, their number and character become of vital importance in estimating the probable success of additional marketing facilities. Hence, if from a conservative study of local conditions and as a strictly business proposition, it does not appear that a cooperative company is likely to be successful, its organization had better be held in abeyance.

PROSPECTIVE MEMBERSHIP.

Having studied the local conditions and the need for organization, it will be desirable to test the community sentiment and desire. A cooperative elevator to be successful must, first of all, have a membership considerable in number and sufficient to insure a dependable patronage from the start. Prospective membership should be determined, if possible, by actual personal canvass of the community. General mass meetings are desirable for the purpose of acquainting the public with the principles of cooperative marketing and for the purpose of free and open discussion of the need therefor; but for the purpose of a concrete and physical appraisal of membership, nothing will serve so well as a formal expression from each interested person. Every community has "chronic enthusiasts" who are in favor of everything that is proposed, but who, when the time comes for assuming definite obligations, find it easier to make excuses. The personal canvass may be made at any time, before, at, or following a general meeting, when the people have been thoroughly acquainted with the objects of the proposed organization.

CAPITAL.

The matter of capital requirement is important and the preliminary survey should be extended to cover a careful estimate of the

capital which the prospective membership may be expected to furnish. This estimate will be of value in apportioning the equitable share of the total capital requirement that each member should furnish when solicited for stock subscription and when the capital requirement has been definitely determined.

Too often subscription lists are circulated and prospective members solicited to subscribe for as much as they can afford up to a certain maximum amount. This method may be effective in raising the required amount of capital quickly, but may also result in eliminating many desirable members because of relaxation of effort when sufficient capital is in sight. Prospective members will subscribe more readily and more liberally when solicited for a definite amount, which has been determined and apportioned according to an equitable estimate of what should be furnished by each.

VOLUME OF TRADE.

Under the head of local conditions, brief reference has been made to the volume of business that might be expected to originate in the community as a whole and its division among already existing agencies. A consideration of prospective volume from this angle is important, but in addition a careful canvass should be made of the patronage which prospective members may be depended upon to furnish. While considerable patronage may be obtained from nonmembers when such patronage is solicited, it is better not to depend upon it, for not infrequently the possible increase in volume from this source is more than offset by patronage which members will give to other agencies and dealers. It is a mistake to assume that when a cooperative elevator has been established it will receive most of the local grain business as a matter of course. While successful cooperative elevators usually handle the bulk of a station's grain, they do so because of having first laid a substantial foundation in the form of a large producing membership.

METHOD OF SURVEY.

First, one or more general meetings may be held, at which the need and readiness of the community for cooperative organization should be thoroughly discussed. Every person present should have an opportunity to express himself, but the meeting should not take the form of a protest meeting in which one or two persons are allowed to monopolize the time in abusing the existing agencies and dealers. Such procedure results only in estranging men who come for constructive purposes and for discovering practical means to improve their condition. It will be desirable to have present some person who understands cooperative organization and marketing methods for the purpose of answering questions and outlining organization plans. Such assistance usually can be obtained upon

application to the agricultural college of the State or to the Bureau of Markets, United States Department of Agriculture. In a number of States there are farmers' grain dealers associations whose secretaries are in a position to furnish valuable assistance.

At or following these meetings, or in lieu of them, where it is found desirable to conduct the preliminary survey quietly, a tentative subscription list may be circulated on which is shown the names of prospective members, the amount of capital which each prospective member thinks he can subscribe, and a conservative estimate in bushels of the grain which he markets annually.

It may seem to be a duplication of effort to secure this tentative list of subscribers, and there may be conditions under which it will be desirable to eliminate it. In any event a list of prospective members, with an estimate of the capital and patronage to be furnished by each, should be prepared in some form. This list may be used to advantage as a basis for study and apportionment when later the actual capital subscriptions are solicited.

The preliminary survey may be made by committees appointed at the first general meeting or by persons interested in the project. If it is impracticable to secure actual signatures to the tentative subscription list, then a list should be prepared in memorandum form, from the best information available and with the assistance of some one having an extensive acquaintance and knowledge of persons and property in the community.

When the survey of local conditions and prospective membership, capital, and patronage has been completed, it will be desirable to determine in a general way the character and cost of the plant and equipment necessary to handle the business. Again, the advice of other associations in successful operation will be valuable. Contractors and builders of elevators will usually furnish estimates and sometimes blue prints and plans for elevators of varying capacity. No intensive study of building plans is necessary at this time. The approximate amount of capital required to provide a plant is the only purpose of the study.

ORGANIZATION.

ORGANIZATION MEETING.

Assuming that the preliminary survey has shown an economic need and a genuine community desire for organization, we are ready to consider organization procedure. At this stage it will be necessary to call a general meeting for the purpose of perfecting a temporary organization and appointing the various committees necessary to carry on the actual work of organization. In case former meetings have been held and have been well organized and

conducted with parliamentary form and order, the chairman and secretary of these meetings may act at the present meeting. If no former meetings have been held, the house should proceed to elect a chairman and secretary and appoint the following committees: (1) Committee on membership and stock subscription; (2) committee on incorporation and by-laws; and (3) committee on buildings and plant site.

These committees may consist of any number of persons but should not be made too large. From three to five members on each committee are sufficient, and no objection can be made to having the same person serve on more than one committee.

At this meeting the plan of organization should be thoroughly discussed in order that the several committees may be instructed relative to the wishes of those present. If the preliminary survey has been well conducted, a report, together with the recommendations of the committee or persons conducting it, will furnish a substantial basis upon which to build the organization plans proper. The amount of capital, number of members, and probable volume of business to be depended upon will be approximately known, and the amount of capital stock and the number and par value of shares should be fixed at this meeting. It will be desirable also to consider some of the more important cooperative principles to be embodied in the by-laws, for which purpose the form of by-laws suggested in this bulletin may be presented and discussed.

BY-LAWS.

While the organization is yet of temporary character and therefore is without authority to adopt by-laws that will be binding upon the future subscribers or stockholders, it sometimes is found desirable, if a large number of prospective members are present, to adopt such by-laws tentatively, and even to elect the directors, who may later be made permanent. If this course is followed, the by-laws should be considered as carefully and as seriously as if the action were final, for it will be expected that the persons who later act as incorporators, and who then go through the form of legally adopting the by-laws and electing directors, will follow to the letter the actions taken by the larger body of prospective members. Some States require that the names of the first directors appear in the charter; in others it is necessary to secure a license for commissioners to solicit stock subscriptions. The form differs in different States, but when definite and complete by-laws can be adopted by a large number of the prospective members, even if this action is without legal effect, it provides something tangible to work on, and the actual work of perfecting a duly incorporated organization according to statutory

form becomes a simple matter. As a matter of fact, formal organization, including incorporation, adoption of by-laws, and election of the first directors, is a technical procedure that can be carried out more expeditiously and with greater exactness by a small number of incorporators than by a large body of members meeting under conditions not always favorable to deliberate and orderly procedure.

A form of by-laws that is believed to embody the principles of cooperation most necessary to observe in a cooperative grain elevator company is given below. With slight modifications it should furnish a practical plan of organization under the laws governing capital stock forms of cooperative associations and companies in most of the grain States.

The notes following some of the sections are explanatory, and, of course, are to be omitted in the by-laws adopted by the organization. The by-laws when read in connection with the explanatory notes are thought to be sufficiently descriptive of the plan without further detail here.

These by-laws should be regarded as suggestive only, and they should be changed to meet the individual and local needs of an association as well as to conform to governing State laws.

SUGGESTED FORM OF BY-LAWS FOR COOPERATIVE GRAIN ELEVATOR COMPANIES.¹

ARTICLE I.—CORPORATE PURPOSE.

Section.

1. Name and location.
2. Objects.
3. Powers.

ARTICLE II.—CAPITAL STOCK.

1. Authorized.
2. Treasury stock.
3. Stock certificates.
4. Stock receipts.
5. Stock transfers.
6. Lost certificates.

ARTICLE III.—MEMBERSHIP.

1. Qualifications.
2. Termination.
3. Restrictions.
4. Reversions.
5. Annual meetings.
6. Special meetings.
7. Notice of meetings.
8. Quorum.
9. Proxies.
10. Order of business.

ARTICLE IV.—DIRECTORS AND OFFICERS.

1. Election of directors.
2. Election of officers.
3. Vacancies.
4. Quorum.
5. Compensation.
6. Removal.

ARTICLE V.—DUTIES OF DIRECTORS.

1. Management of business.
2. Employment of manager.
3. Bonds.
4. Meetings.
5. Annual audits.
6. Depreciation.
7. Educational work.

ARTICLE VI.—DUTIES OF OFFICERS.

1. President.
2. Vice President.
3. Secretary.
4. Treasurer.

ARTICLE VII.—DUTIES OF MANAGER.

1. In general.
2. Duty to account.
3. Duty to insure.
4. Control of help.

¹ These by-laws were prepared with the cooperation of secretaries of State Farmers' Grain Dealers Associations.

ARTICLE VIII.—EARNINGS.

1. Apportioned :
 - (a) Surplus.
 - (b) Dividend on capital stock.
 - (c) Educational.
 - (d) Patronage refund.
2. Method of refund :
 - (a) Grain rate.
 - (b) Miscellaneous products rate.
 - (c) Merchandise rate.
3. Members' share.
4. Nonmembers' share.
5. Disposal of unapportioned share and nonmembers' unapplied refund.
6. Notice of refund due nonmembers.
7. Capital impairment.

ARTICLE IX.—SUNDRY PROVISIONS.

1. Fiscal year.
2. Indebtedness.
3. Extension of credit.
4. Collective buying.
5. Withholding dividends.
6. Withholding patronage refunds.
7. Emergency capital.
8. Speculation.
9. Corporate seal.
10. Amendments.

ARTICLE I.—CORPORATE PURPOSE.

SECTION 1. *Name and location.*—This Association shall be known as [The _____ Grain Growers' Cooperative Association]¹ and shall be incorporated under the laws of the State of _____. Its principal office shall be located in the town of _____, county of _____, in the State of _____.

NOTE.—Some of the State cooperative laws provide that the word "cooperative" shall form a part of the name of organizations incorporated thereunder. All associations should be incorporated under the laws of the State in which they are located.

SEC. 2. *Objects.*—The objects of this Association shall be to encourage better and more economical methods of production; to save to its members and others all unnecessary cost in the marketing and distribution of grain, seeds, live stock and farm products of all kinds; to buy cooperatively fertilizers, feeds, fuel, machinery, and all material and supplies ordinarily used on the farm; to cultivate and develop cooperative activity, and to perform any other work which may tend to benefit its members or the community in general.

SEC. 3. *Powers.*—This Association shall have power to buy and sell and otherwise deal in, for its own account or on commission, any or all of the products and supplies described in section 2 hereof; to operate grain warehouses and flour and feed mills; to prepare and distribute cooperative literature and educational matter; to lease, buy, build, own, improve, mortgage, sell, and control such buildings and other real and personal property as may be necessary to conduct the business or as the association may from time to time determine. It shall have power to affiliate and cooperate, by membership or otherwise, with any other cooperative company or association; to subscribe and invest, not to exceed [twenty-five per cent] of its capital stock and surplus, in the capital stock of any other cooperative company or association having the same or similar objects and purposes as this Association, but no such action shall be taken except at a regular meeting or a special meeting called for the purpose at which [a majority] of all the members shall be present or voting. It shall have power to do anything and everything, not inconsistent with law, which is necessary or desirable to accomplish the objects and purposes herein stated.

NOTE.—The objects and powers of the Association should be stated as definitely as possible, but they should also be made sufficiently broad to cover any future activities. State statutes will have to be consulted in order to determine what may or may not be included in this article.

¹ All matter appearing in brackets is suggestive only and is to be altered to suit the best interests of each individual association.

ARTICLE II.—CAPITAL STOCK.

SECTION 1. *Authorized.*—The authorized capital stock of this Association shall be [twenty-five thousand dollars] divided into [five hundred] shares of the par value of [fifty dollars] each. All shares shall be full paid and non-assessable and the Association shall not commence business until [fifteen thousand dollars] shall have been subscribed and paid in.

NOTE.—The amount of capital stock must be determined with reference to the cost of plant, the volume of business to be handled, and the membership of the Association. Share value must be low enough not to exclude any one from membership yet high enough to provide the necessary capital.

SEC. 2. *Treasury stock.*—The treasury stock of this Association shall consist of such issued and outstanding stock of the Association as may be donated to or otherwise be acquired by it, and shall be held subject to disposal by the Board of Directors.

SEC. 3. *Stock certificates.*—Certificates of stock shall be issued to each holder of full-paid stock. Each certificate shall state the par value of the stock, the number of shares represented, the name of the person to whom issued, and shall bear the signatures of the President and Secretary and the seal of the Association and be numbered and issued in numerical order from the stock certificate book. Each certificate shall bear the following statement:

"This certificate No. — is issued and accepted in accordance with and subject to the conditions and restrictions stipulated in the By-Laws and amendments to the By-Laws of [The — Grain Growers' Cooperative Association] and more specifically in [section 5 of Article II and sections 2, 3, and 4 of Article III] to wit: [Herein insert those sections of By-Laws which relate to transfer of shares, termination of membership, and restrictions upon share ownership and voting power], all of which is made a part of the signed agreement and receipt which appears on the stub-record bearing the same number and date as this certificate."

SEC. 4. *Stock receipts.*—A record of each certificate of stock issued shall be kept on the stub thereof and each certificate issued shall be receipted for on the stub in the following form:

"In consideration of the issuance to me of this certificate of stock No. — for — shares of the capital stock of [The — Grain Growers' Cooperative Association] of —, —, I do hereby agree to all of the conditions, restrictions, limitations, and reservations stipulated in the By-Laws and amendments to the By-Laws of this Association, and more specifically in [section 5 of Article II and sections 2, 3, and 4 of Article III], which are set out in full on the certificate and made a part of this agreement. I have received the said certificate of stock this — day of —, 19—.

(Signature of Member.)

Witness: _____

NOTE.—Printing the By-Law restrictions upon the body of the stock certificate is a convenient and effective means of giving notice of such restrictions to intending purchasers. The receipt form here suggested will constitute a written contract relative to the observance of these restrictions.

SEC. 5. *Stock transfers.*—Transfers of stock shall be made only upon the books of the Association, and before a new certificate is issued the old certificate must be surrendered for cancellation. The transfer of stock may be refused unless any and all indebtedness to the Association by the member shall first be paid. The stock books of the Association shall be closed for transfer [ten] days before

the annual membership meeting and [ten] days before the time set for payment of interest and patronage refunds.

SEC. 6. *Lost certificates.*—The Board of Directors may order new certificates of stock to be issued in the place of any certificates alleged to have been lost or destroyed, but the owner of the lost certificate shall first cause to be given to the Association a bond in such sum, not less than the par value of such lost or destroyed certificate, as said Board may direct, as indemnity against any loss or claim that the Association may incur by reason of such issuance of stock certificates, or, in the discretion of the Board of Directors, a new certificate may be issued upon filing with the Secretary an affidavit properly certifying the loss of the original certificate.

ARTICLE III.—MEMBERSHIP.

SECTION 1. *Qualifications.*—Any producer of farm products or any person who may be a user of any of the products and supplies handled by the Association and a patron or prospective patron thereof in any territory tributary to the shipping points of this Association may upon application accepted by the Board of Directors become a member of this Association by agreeing to comply with the requirements of these By-Laws and becoming the owner of at least one share of its capital stock.

NOTE.—There may be conditions under which it would be wise to limit membership to those who have been recommended by the Board of Directors or who have received a two-thirds vote of the members present at any meeting.

SEC. 2. *Termination.*—At any time a member shall remove from the territory tributary to the shipping points of this Association, the Association may elect to purchase his shares of stock and to terminate his membership upon tender to him of the book value of his shares as determined from the last preceding financial statement, together with any dividends or refunds due and unpaid, less any indebtedness then due the Association. Such shares shall then become treasury stock of the Association.

SEC. 3. *Restrictions.*—No member shall own more than ----- shares of the capital stock of this Association at any one time, and no member shall be entitled to have more than one vote at any meeting of the members, regardless of the number of shares owned. Every member upon uniting with this Association agrees that in case he shall desire to dispose of his shares of stock in the Association, the Association shall have the first right to purchase the same at their book value, and that no offer of assignment or sale shall be made to any person or interest until the Association shall fail either to waive this right or to purchase the shares after ----- days' notice in writing.

Any transfer of shares by assignment or sale shall give the assignee or purchaser no other right than to require upon ----- days' notice in writing, an election by the Board of Directors either to admit the holder to membership or to tender him the book value of such shares together with any dividends and refunds then due and unpaid.

SEC. 4. *Reversions.*—If any member shall by purchase or by operation of law come into possession of more than ----- shares of the capital stock of this Association, the Board of Directors may elect to purchase such excess shares upon tender to him of the book value thereof together with any dividends or refunds due and unpaid. Also in the event of the death or disability of the owner of any shares of stock in this Association, such shares of stock shall revert to the Association upon the tender of payment by it to his heirs or legal

representative, the book value of same together with any dividends or refunds due and unpaid, or it may elect to transfer such shares to his heirs or legal representatives.

NOTE.—For legal effect, sections 2, 3, and 4 above depend entirely upon the charter provisions and the laws of the State in which the Association is incorporated. They are suggested here as possible means of safeguarding cooperative principles and are to be incorporated into or excluded from the By-Laws upon the advice of competent legal counsel.

SEC. 5. *Annual meeting.*—The annual meetings of the members of this Association shall be held in the town of -----, State of ----- on the [last ----- in -----] of each year at one o'clock p. m., if not a legal holiday, but if a legal holiday on the next business day following.

NOTE.—A number of companies have determined upon Saturday for the annual meeting, but it is suggested that some other day may be better, since among many farmers Saturday is given to shopping and other business affairs, making it difficult to secure an interested attendance.

SEC. 6. *Special meetings.*—Special meetings of the members may be called at any time by resolution of the Board of Directors and shall be called at any time upon the written request of [a majority] of the members. Such request shall state the time and place of meeting and the object of meeting.

SEC. 7. *Notice of meetings.*—Written or printed notice of meetings for every regular or special meeting of the members shall be prepared and mailed to the last known post-office address of each member not less than ---- days before a regular meeting, nor less than ---- days before a special meeting, and if for a special meeting such notice shall state the object or objects thereof and the time and place of meeting.

SEC. 8. *Quorum.*—A quorum shall consist of — of the members qualified under section 1, hereof, represented in person. A majority of such quorum shall decide any question that may come before the meeting, except as otherwise provided.

NOTE.—When the organization is small and compact, the proportion required for a quorum may be larger than in a large organization which includes considerable territory.

SEC. 9. *Proxies.*—Voting by proxy shall not be permitted, but absent members may vote on specific questions, other than the removal of directors, by ballots transmitted to the Secretary of the Association by registered mail, and such ballots shall be counted only in the meeting at the time at which such vote is taken.

SEC. 10. *Order of business.*—The order of business at the annual meeting and so far as possible at all other meetings of the members shall be:

- (1) Calling of roll.
- (2) Proof of due notice of meeting.
- (3) Reading and disposal of any unapproved minutes.
- (4) Annual reports of officers and committees.
- (5) Election of directors.
- (6) Unfinished business.
- (7) New business.
- (8) Adjournment.

ARTICLE IV.—DIRECTORS AND OFFICERS.

SECTION 1. *Election of Directors.*—The Board of Directors of this Association shall consist of [seven] members. The members of the first Board of Directors shall hold office until the first annual meeting of the members, when

their successors shall be elected from among the membership of the Association for terms of office as follows: [Three] for one year, [two] for two years and [two] for three years. Upon the expiration of the terms of the directors so elected their successors shall be elected for terms of [three] years. Directors shall hold office until their successors shall have been elected and have qualified and entered upon the discharge of their duties. The elections shall be by ballot and each member of record shall be entitled to cast one and only one vote for each Director to be elected. All elections except the first shall be conducted by two inspectors appointed by the President for the purpose.

NOTE.—In some States the corporation laws stipulate the number of Directors and officers an association shall have. If possible the Board of Directors should be so constituted that the various sections and geographical centers are represented. This tends to avoid jealousy and strengthens the confidence of the members. Some object to having a Director hold office for more than one year, claiming that the Board might be so objectionable to the members that it would be desirable to elect an entirely new Board at the annual meeting. However, there are many advantages in keeping some experienced Directors on each Board. In case the entire Board should go contrary to the wishes of the members, the recall of each Director could be effected under section 6 of this article. A number of companies have adopted the plan of having Directors elected for one year but provide that in elections the names of all the old Directors must be placed in nomination and that the number of additional nominees shall be less than one-half of the whole number of Directors. This arrangement effects to retain on the Board a number of members who are experienced; at the same time it affords opportunity to dispose of old members who may have proven unsatisfactory.

SEC. 2. *Election of officers.*—The Board of Directors shall meet within [ten] days after the first election and within [ten] days after each annual election, and shall elect by ballot from among themselves a President, Vice President, Secretary, and a Treasurer [or a Secretary-Treasurer]. Such officers, unless sooner removed, shall hold office for [one] year or until their successors are elected and have qualified.

SEC. 3. *Vacancies.*—Any vacancy in the Board of Directors shall be filled for the unexpired term at any annual meeting or at any special meeting called for the purpose in the manner provided for the original election of Directors. If any Director shall cease to be a member his office shall be declared vacant.

SEC. 4. *Quorum.*—A majority of the Board of Directors shall constitute a quorum at any meeting of the Board of Directors, but no proposition shall carry unless at least — members of the Board shall vote in the affirmative.

NOTE.—It will be convenient to permit less than the full number of Directors to transact business, but there may be occasions when it would be desirable to guard against action by a mere majority of the minimum number required for a quorum.

SEC. 5. *Compensation.*—The compensation of the Directors and officers other than the Manager shall be determined by the members of the Association at any regular or special meeting of the Association.

SEC. 6. *Removal.*—Any Director of the Association may, for cause, at any annual or at any special meeting called for the purpose, at which a majority of the members shall be present, be removed from office by vote of not less than [two-thirds] of the members present. Each Director shall be informed in writing of the charges preferred against him at least [ten] days before such meeting and at such meeting shall have an opportunity to be heard in person, or by counsel, and by witnesses in answer thereto. Officers or agents of the Board of Directors may be removed from office or employment at any time by action of the Board of Directors.

NOTE.—In some cases, especially when the Board of Directors is large, it is desirable to have an executive committee. Such a committee can be made up of the President and two or more members of the Board.

ARTICLE V.—DUTIES OF DIRECTORS.

SECTION 1. *Management of business.*—The Board of Directors shall have general supervision and control of the business and the affairs of the Association and shall make all necessary rules and regulations not inconsistent with law or with these By-Laws, for the management of the business and the guidance of the officers, employees, and agents of the Association. They shall have installed an accounting system which shall be adequate to the requirements of the business, and it shall be their duty to require proper records to be kept of all business transactions.

NOTE.—The Bureau of Markets has devised systems of accounts for several lines of cooperative business, such as grain elevators, fruit organizations, creameries, live stock shipping associations, and stores. Information regarding systems of accounts may be obtained by writing to the Bureau of Markets, U. S. Department of Agriculture.

SEC. 2. *Employment of manager.*—The Board of Directors shall have power to employ and to dismiss a business manager, and to fix his compensation.

SEC. 3. *Bonds.*—The Board of Directors shall require the Manager and all other officers, agents, and employees charged by the Association with responsibility for the custody of any of its funds or property to give bond for the same. Such bond shall be furnished by a responsible bonding company approved by the Board of Directors, and the cost thereof shall be paid by the Association.

NOTE.—It is advisable to have bonds furnished by a bonding company for the reason that such companies usually investigate the past record of all applicants for bond, and also endeavor to keep a check upon their habits and behavior while bonded, thus rendering a specific service in addition to the bond protection.

SEC. 4. *Meetings.*—The Board of Directors shall meet four times per year, at least once in each quarter, at the principal office of the Association. Special meetings of the Board shall be held upon call of the President or upon written request of [three] members of the Board.

SEC. 5. *Annual audits.*—At least once in each year the Board of Directors shall secure the services of a competent and disinterested auditor or accountant, who shall make a careful audit of the books and accounts of the Association and render a report in writing thereon, which report shall be submitted to the members of the Association at their annual meeting. This report shall be based upon an actual physical inventory of all property, produce, merchandise, and moneys belonging or owing to and by the Association, and the last report shall furnish the basis for determining the book value of the shares of capital stock.

SEC. 6. *Depreciation.*—Annually the Board of Directors shall cause to be charged as part of the operating expense of the Association an amount not less than — per cent of the original value of all buildings, — per cent of the original value of all machinery, and — per cent of the original value of all office fixtures and equipment, which amount shall be reserved for depreciation.

NOTE.—Five per cent on frame structures, 2½ per cent on concrete and brick, and 10 per cent on machinery and office fixtures is generally regarded as reasonable. The rate of depreciation should be fixed with reference to kind of property and deductions allowable in making income tax returns under the Internal Revenue Laws.

SEC. 7. *Educational work.*—The Board of Directors are authorized to conduct educational work for the purpose of stimulating interest in cooperative activity; to subscribe for and have sent to the members such cooperative literature and publications as they may determine upon, and to obtain membership for this Association in any State association or other organization of cooperative companies which may tend to further the object and purposes of this Association.

ARTICLE VI.—DUTIES OF OFFICERS.

SECTION 1. *President*.—The President shall preside over all meetings of the Association and of the Board of Directors, sign as President with the Secretary or Secretary-Treasurer all stock certificates, notes, deeds, contracts, conveyances, agreements, and other instruments requiring such signatures, call special meetings of the Association and of the Board of Directors, and perform all acts and duties usually required of an executive and presiding officer.

SEC. 2. *Vice President*.—In the absence or disability of the President, the Vice President shall preside and perform the duties of the President.

SEC. 3. *Secretary*.—The Secretary shall keep a complete record of all meetings of the Association and of the Board of Directors, sign as Secretary, with the President, all stock certificates, notes, deeds, contracts, conveyances, agreements, and other instruments requiring such signature; serve all notices required by law and by these By-Laws; keep a complete record of all business of the Association, and make a full report of all matters and business pertaining to his office to the members at the annual meeting; make all reports required by law, and perform such other duties as may be required of him by the Association or by the Board of Directors.

SEC. 4. *Treasurer*.—The Treasurer shall receive, have the custody of, and disburse such moneys, notes, and securities as may come into his possession by virtue of his office or by direction of the officers of the Association, and shall not pay out any of the moneys so received or notes or securities held except on a written order of the Secretary countersigned by the President, unless otherwise ordered by the Board of Directors.

ARTICLE VII.—DUTIES OF MANAGER.

SECTION 1. *In general*.—Under the direction of the Board of Directors the Manager shall have general charge of the ordinary and usual business operations of the Association, including the purchasing, marketing, and distributing of all products and supplies; he shall conduct the business on a margin-above-cost basis, which margin shall be uniform and just on each kind or grade of grain, products, and supplies handled and which shall at all times be sufficient to meet the annual operating expenses and to provide the funds stipulated by divisions *a*, *b*, and *c*, of section 1, Article VIII, hereof. He shall deposit all moneys which come into his possession in a bank selected by the Board of Directors, and shall make all disbursements therefrom by check.

SEC. 2. *Duty to account*.—He shall be required to maintain his records and accounts in such manner as will at all times show the true and correct condition of the business. He shall render annual and periodical statements in the form and in the manner prescribed by the Board of Directors. He shall carefully preserve all books, documents, correspondence, and records of whatever kind pertaining to the business which may come into his possession. He shall prepare daily and file in the Association's office a grain statement which shall show the total amount of each kind of grain in the elevator, in transit unsold, contracted from farmers and undelivered, together with the total amount in store and due on open sales as well as the amount represented by purchases or sales of futures, all of which shall be arranged to show the net amount of each kind of grain long or short at the close of business each day.

SEC. 3. *Duty to insure*.—He shall be required at all times to keep the property of the Association well and fully insured which insurances must extend to and cover grain and property of all kinds, regardless of ownership, which may be in possession of the Association or stored by it.

SEC. 4. *Control of help.*—He shall have control over and may employ and dismiss all agents and employees of the Association not specially employed by the Board of Directors.

NOTE.—The principal responsibility for success falls upon the Manager, and his power should be limited as little as possible. If he can not be trusted to administer the details of all the ordinary and usual business operations, he should be replaced with a Manager who is worthy of full confidence. The Manager and the Board of Directors should work together, but meddling on the part of individual members should not be tolerated. When cooperative elevators become involved in financial difficulty the cause is frequently due to speculation, not in futures nor always intentionally, but simply through failure to know each day the exact status of grain contracts, purchases, sales, and hedges. For this reason the daily grain statement in section 2 should be insisted upon.

ARTICLE VIII.—EARNINGS.

SECTION 1. *Apportioned.*—At the end of each fiscal year the total net earnings of the Association which remain over and above all expenses and a reserve for depreciation shall be apportioned in the following manner:

(a) *Surplus.*—There shall be appropriated for the purpose of creating a surplus not less than [ten] per cent of the net earnings until such surplus shall equal at least [fifty] per cent of the capital stock paid.

(b) *Dividend on capital stock.*—There shall be appropriated for the purpose of providing a dividend on capital stock a sum which shall equal but not exceed [six] per cent of the amount of capital stock issued and outstanding.

(c) *Educational.*—There may be appropriated for educational purposes and for promoting cooperation and improvement in agriculture a sum equal to [five] per cent of the net earnings.

(d) *Patronage refund.*—The remainder of the net earnings shall be apportioned upon patronage in accordance with the method stipulated in section 2.

SEC. 2. *Method of refund.*—The earnings upon grain operations, the earnings upon miscellaneous products, and the earnings upon supplies and merchandise operations shall be segregated into groups (a), (b), and (c), respectively. Additional groups shall be established only as are necessary to provide for various commodities handled on widely varying net margins. Special transactions handled on the basis of actual cost of service shall be excluded in computing patronage refunds hereunder.

(a) *Grain rate.*—The total net earnings which accrue from grain operations after deducting an equitable proportion of all expenses and the appropriations provided for in section 1 shall be divided by the total number of bushels of grain of all kinds bought by the Association during the year. The result shall be the patronage refund rate per bushel to be applied to grain purchased from members.

(b) *Miscellaneous products rate.*—Patronage refund rates for other products bought by the Association shall be determined in the same manner as provided for grain except that they may for convenience be determined upon the basis of money value, instead of per unit, at the discretion of the Board of Directors.

(c) *Merchandise rate.*—The total net merchandise earnings which accrue from merchandise and supplies operations after deducting an equitable proportion of all expenses and the appropriations provided for in section 1 shall be divided by the total volume in dollars of the merchandise sales during the year. The result shall be the patronage refund rate in per cent to be applied to merchandise sales.

NOTE.—When various kinds of products and supplies or merchandise are handled it may be desirable to establish different rates of refund based upon differences in margins and handling costs. In this case those commodities which carry the same or nearly the same margins and handling costs should be grouped and refund rates established to apply to each group. It will not be necessary except in rare instances to establish different rates of refund for the different kinds of grain handled. It is

almost the universal practice to fix the buying margins for the different kinds of grain with special reference to differences in handling cost. Therefore no further apportionment of expense is necessary, since the net margins will be about the same. Excessive earnings which accrue on some particular kind of grain usually are due to market changes after the grain has been bought from the farmers and are not the result of differences in first-hand buying margins. Exceptions will, of course, have to be made of certain kinds of grain handled under abnormal conditions.

SEC. 3. *Members' share.*—Each member shall receive patronage refund based upon the total volume of grain and other products sold to the Association and the volume of supplies and merchandise of all kinds bought from the Association during the year, which shall be computed by applying the refund rates as determined under division (a), (b), and (c) of section 2 hereof.

SEC. 4. *Nonmembers' share.*—Each nonmember may receive patronage refunds under the provisions of this article at ----- the rate which is paid to members, provided that refunds appearing to his credit may first be applied to the purchase for him of one or more shares of the capital stock of this Association.

SEC. 5. *Disposal of unapportioned share and nonmembers' unapplied refund.*—If nonmembers share in patronage refunds at a rate less than the rate paid to members the difference may be diverted to the surplus of the Association or may be distributed among the members in such manner as the Board of Directors may determine. In like manner any portion of the patronage refunds payable to nonmembers which is not accepted under the conditions of section 4 may be similarly diverted or distributed, but patronage refunds payable to nonmembers shall be carried under separate account for a period of [two] years before being so diverted or distributed.

NOTE.—For the purpose of making income-tax returns under the Internal Revenue Laws, the special dividend provided for in this section should be kept separate from the refunds accruing upon members' patronage.

SEC. 6. *Notice of refund due nonmembers.*—At least once each year there shall be mailed to each nonmember entitled to refund, a notice which shall state the amount of refund due and the conditions under which the refund will be made, and which shall contain a suitable form of application for membership.

SEC. 7. *Capital impairment.*—In no event shall dividends on capital stock as provided for in division (b) of section 1, hereof, be paid out of the capital stock, but in case the earnings of the Association in any year shall be insufficient for this purpose, a sum equal to such deficiency may be set aside from the earnings of the following year before any portion of these earnings is made available for patronage refunds.

NOTE.—This article may appear to be unnecessarily specific and detailed, but a simple statement that earnings over and above expenses and certain reserve items shall be distributed on the basis of patronage furnished is capable of various interpretations and applications, and it is believed that a practical and definite plan should be determined upon and incorporated into the By-Laws in order that it may be applied uniformly at all times.

ARTICLE IX.—SUNDRY PROVISIONS.

SECTION 1. *Fiscal year.*—The fiscal year of this Association shall commence ——— and end on the ——— day of the following ———.

NOTE.—Whenever possible, the fiscal year should end after the close of one season's business and before the opening of the next. Thus, a grain elevator usually has its fiscal year ending in spring or early summer, when practically all of the work of handling the previous season's business has been finished.

SEC. 2. *Indebtedness.*—The amount of indebtedness which may be incurred by or in behalf of this Association shall not at any one time exceed [two-thirds] of the paid capital stock.

SEC. 3. *Extension of credit.*—The business of this Association shall so far as possible be conducted on a cash basis. All accounts due and unpaid at the end of thirty days shall bear interest at the rate of — per cent from the date of sale and all sales tickets or bills of sale shall so state.

SEC. 4. *Collective buying.*—All merchandise purchased through the Association, other than that regularly carried in stock, shall be paid for in cash by the members ordering such supplies at the time of ordering the same, or the money may be deposited with a bank which has been approved by the Board of Directors, at the time of ordering.

NOTE.—Without such protection an organization purchasing supplies for its members may find that some of the members will refuse to take supplies ordered or will not pay promptly.

SEC. 5. *Withholding dividends.*—The Board of Directors may withhold the payment of a dividend on stock when in their judgment the condition of the business requires it, but no patronage refunds shall be paid during the period so withheld.

SEC. 6. *Withholding patronage refunds.*—The Board of Directors may withhold the payment of patronage refunds when in their judgment the condition of the business requires it. In every such case, however, each member shall be credited upon the patronage refund register or similar record with the amounts so withheld, and these funds shall not be confused with the surplus provided for under division (a) of section 1, Article VIII.

NOTE.—Withholding the dividends and refunds provided for in sections 5 and 6 furnishes working capital during the time in which the surplus is being accumulated gradually by the appropriation of 10 per cent of the annual net earnings. When the financial condition of the company will permit, the dividends or refunds of prior years may be paid. By this method the surplus is not accumulated at the expense of those who patronize the company during its first years of existence.

SEC. 7. *Emergency capital.*—At the time of uniting with this Association or at any time thereafter, when called upon by the Board of Directors, each member shall deliver to the Association his negotiable promissory note, payable on demand, to the order of the Association. Such note shall be for the sum of [twenty-five dollars] plus ——— per acre additional for each acre of crops to be grown by the members whose products are to be marketed through the Association. These notes shall be the property of the Association for the purpose of being pledged by the Board of Directors as collateral security for any loan that may be necessary in the conduct of the business of the Association. Any member's note shall be available in the settlement of any damage to the Association that may result from the failure of said member to make good his contracts.

NOTE.—This section is intended to supply capital which is needed only for short periods, as, for instance, during crop-moving time and other periods when emergency capital is required. Organizations which have a surplus for such purpose may not find it necessary to include this section in their By-Laws. If any member knows that the Association holds his note, which may be sold to settle any damage caused by his breach of contract, it will probably cause him to comply more carefully with the terms of that contract.

SEC. 8. *Speculation.*—Neither the Manager nor any other agent or employee of this Association shall during the period of his term of office or employment be permitted to deal or trade in futures or options in grain or other commodities or stocks in his own name or in the name of any other person or in the name of this Association except as it may be necessary to hedge actual purchases or holdings of grain or sales of stored grain and then only with the knowledge and consent of the Board of Directors. This Association shall so far as it is practicable avoid any and all speculation in grain, and shall not at any one time accumulate by purchase or contract an amount which in the aggre-

gate shall exceed ----- bushels unless the same shall be resold or be properly protected by sales of futures.

SEC. 9. *Corporate seal.*—The corporate seal of this Association shall consist of two concentric circles, between which shall be the name of this Association, and in the center shall be inscribed “[Incorporated 1920, Iowa.]” and such seal is hereby adopted as the seal of the Association.

SEC. 10. *Amendments.*—These By-Laws may be amended, repealed, or altered, in whole or in part, at any regular meeting of the members, or at any special meeting, when such action has been duly announced in the call, provided that three-fourths of the entire membership shall vote for such amendment, repeal, or alteration.

NOTE.—Any other matter which it is deemed desirable to regulate in the By-Laws may be provided for in this article.

STOCK SUBSCRIPTION AND MEMBERSHIP.

The work of the committee appointed to secure stock and membership subscriptions should proceed along lines which have been worked out carefully in advance. The entire community or territory from which membership is to be drawn should be laid off in districts and men should be selected to canvass the district who have a wide acquaintance and are favorably known in the community. The subscription lists may be circulated by persons other than those named on the subscription committee. It is neither necessary nor always advisable to have the men work in their own immediate neighborhoods. A record should be kept of each solicitor of the persons visited who have failed to subscribe and of the reasons given. If possible, these persons should be visited a second time by a different solicitor, in order to make sure that they have been approached in the right manner and that failure to subscribe is not due to personal differences between them and the first solicitor. It sometimes occurs that men who would make excellent members and who at heart are in favor of the enterprise will refuse to sign a subscription contract presented by a person whom they dislike. If possible, men who are generally regarded as substantial and of good judgment and enterprise should be visited first and their names secured to head the lists. The capital stock subscription contract (form No. 1) in the Appendix will furnish a model for subscription lists.

It will be desirable wherever possible to have the capital stock subscriptions solicited by a local committee. The employment of a special salesman to place the stock on a commission basis is seldom advisable and should be resorted to only when it is impossible to secure the right type of men to serve on the committee. In some States the selling of stock in a cooperative company on a commission basis is prohibited by law. When it is found necessary to employ a paid solicitor, the stock should in every case be sold at an amount above par sufficient to provide for his commissions. Selling the stock at par and paying a commission thereon burdens the com-

pany with a deficit at the outset. When capital stock can not be placed without the aid of a paid solicitor it may in most cases be taken as an indication that the community is not ready for organization.

In soliciting capital stock subscriptions care should be taken that extravagant statements are not made and that the members are not led to expect the impossible.

INCORPORATION.

When by-laws have been adopted tentatively by the prospective members, they will be used by the committee on incorporation as a basis for drafting the articles of association. If no by-laws have been agreed upon, the committee should draft a tentative form which, as far as it is possible to anticipate, will meet the requirements of the association.

If possible the articles of association should be drafted with the assistance of competent legal counsel and be made to legalize all matters set up in the tentative by-laws. The most able of counsel must know what an organization proposes to do, the activities to be carried on, and the means to be employed, before he can intelligently draft the articles of incorporation, or charter application, as it sometimes is called. It may be that upon examination by counsel the by-laws will be found to contain provisions that are not legal in the State in which the association is to be incorporated. In this case the by-laws will be changed to conform with the law. It may be that some of the objects expressed in the by-laws, which are objectionable in the form stated, may be attained by different means that will readily occur to the counsel when he has before him a definite and orderly statement of those objects. In this connection it may not be improper to point out that very able lawyers sometimes are not thoroughly acquainted with the objects and economic principles that control cooperative companies, and they may with the best of intentions advise organization on some plan with which they are more familiar and which offers less difficulties than does the organization of a truly cooperative association. Herein lies the value of having prepared and decided upon in advance a form of by-laws detailing completely and in orderly form those matters which distinguish the cooperative from the ordinary corporation form which usually appeals to lawyers, bankers, and others who are more familiar with the ordinary form.

The procedure for securing a charter varies in the different States and for that reason no detailed information can be given here. In general it may be effected by having a minimum of from 3 to 25 persons, depending upon statutory requirements, sign the articles of association, which articles or certified copies thereof are filed with certain State and county officers.

MEETING OF INCORPORATORS.

In case by-laws already have been decided upon and are tentatively adopted by the prospective members prior to incorporation, the next meeting becomes merely a perfunctory and formal meeting of the incorporators, who proceed to accept the charter and to legally adopt the by-laws and elect the directors already agreed upon. It is important that careful and accurate minutes be kept of the proceedings at all meetings, but those of the first meeting are especially important. It may be desirable to have a blanket form of minutes prepared in advance which legally and in proper sequence will cover the organization details, and to have the meeting proceed along the lines indicated by this form. (See Form No. 2.) All of the persons whose names appear as incorporators should ordinarily be in attendance at this meeting and the minutes should so indicate. When the number of incorporators is large and it is possible that some of them may be unable to attend the meeting it will be advisable to have them sign what is known as a call and waiver of meeting. This call and waiver of meeting is a notice which, in addition to stating the time, place, and purpose of meeting, contains a stipulation that the persons whose names are signed to it agree and consent to be bound by any action which may be taken at the meeting. (Form No. 3.)

The first order of business at the meeting, whether it consists only of the incorporators, or of the subscribers also, would be a consideration of the reports and recommendations of the several committees. The report of the committee on stock subscriptions and that of the committee on plant type and location will indicate the relation of capital subscribed to the plant capital required. Ordinarily a co-operative elevator company should not be organized until sufficient capital at least to cover the plant investment has been subscribed. It is much easier to secure capital subscriptions before organization than later. When the by-laws have been formally adopted the directors therein provided for should be elected, which completes the organization.

Immediately following the meeting of the incorporators or subscribers, as the case may be, the directors should meet for the purpose of organizing the board and electing their officers. If it is impossible to meet, then they should all sign a call for a future meeting, for as yet no one member has the authority to call a special meeting. This meeting is opened by any one of the members of the board. A temporary chairman and secretary are appointed, followed by the election of permanent officers according to the by-laws form. The board of directors at the beginning of their term in a newly organized company will find much to do and the frequent meetings may be arranged more conveniently by adjournment from time to time than by calling special meetings.

CHANGING FORM OF ORGANIZATION.

It will be highly desirable for those farmers' elevator companies which are cooperative in purpose but for reasons already stated are not cooperative in form or effect to change to the cooperative plan before too many of their members have retired from active farm life and while the interests of producing members are still paramount. The change may be effected in several ways, but only two methods are of special interest to farmers' elevator companies:

(1) In some States the change may be brought about by a formal declaration of intent on the part of the stockholders holding a majority of the voting shares, to come under and be governed by the particular legislative act or statute providing for the incorporation of cooperative companies, and by a certification of the fact to certain State and county officials.

(2) The old corporation may be dissolved and a new one formed to carry on the business on the cooperative plan. In this case the affairs of the old organization should be closed as if reorganization were not intended, but in the distribution of the corporation assets the interests of the individual stockholders in the old organization who desire to be members of the new organization may be assigned in payment for stock in the new organization, unless, of course, capital stock subscriptions are by State law required to be paid in cash. The assets of the old organization thus would be transferred to the new organization and the claims of stockholders in the old organization who are unwilling to become associated with the new one may be settled by cash payment. Under this method new members may be admitted by means of stock subscriptions and the stock interests of old members may be limited or apportioned to the same extent as if they were new members, differences being adjusted by cash payment.

Any method is easily applied when the stockholders of the old organization are unanimously agreed to it. All methods offer difficulties when there are dissenting stockholders. The first method seems to be the one generally used in States in which it is authorized. The following language is typical of State statutes defining the kinds of companies which may take advantage of this method:

All cooperative corporations, companies, or associations heretofore organized and doing business under prior statutes or which have attempted to so organize and do business shall have the benefit of all the provisions of this act and be bound thereby on filing with the Secretary of State a written declaration, signed and sworn to by the president and secretary, to the effect that said cooperative company or association has, by a majority vote of its stockholders, decided to accept the benefits of and be bound by the provisions of this act.

Whether or not an ordinary capital stock corporation, owned and controlled by farmers, but which operates strictly as a profit corporation, and not having recognized or attempted to incorporate into its

by-laws or plan of operation the patronage dividend or other features which especially characterize cooperative companies in the new statute, would be entitled to declare itself a cooperative company for the purpose of coming under the provisions of this law may be open to question. There may be opportunity for proper objection on the part of dissenting stockholders claiming a right to share in future profits under the arrangement in force at the time of becoming stockholders. However, no serious difficulties are usually encountered, since most of the stockholders who are inclined to dissent realize that they can not control against a majority of the members and that they will fare better to accept the terms offered them than to have a new company organized, the old organization abandoned, and its property brought to forced sale in dissolution proceedings.

In reorganizing it sometimes is found desirable to fix the property interest which members have in the surplus or undivided profits of the old organization. Some of the members of the old organization may not wish to be members under the new arrangement; perhaps new members are to be admitted, which makes it necessary to fix the interests of old members before they shall become confused with the interests of new members. Several methods are open, none of which is entirely free from objection under all conditions:

- (1) The surplus may be distributed in the form of a cash dividend.
- (2) The surplus may be distributed in the form of a stock dividend, each member receiving additional stock shares in an amount equal to his share in the surplus.
- (3) The surplus may be left intact but new members may be required to pay for stock an amount above par which will make their contribution to the surplus fund equal to the interests of the other members.

In many instances the business of the old organization has been extended and the surplus employed in such manner as to make it practically impossible to distribute it by cash dividend, and the first method can rarely be employed to advantage.

Many companies find objection to the second method for the reason that increasing the capital stock increases the amount of interest or dividend on capital stock required to be paid before any of the earnings are available for patronage refunds. A more vital objection would seem to be that when the surplus is converted into capital stock the impairment of such capital stock through possible business loss assumes a far more serious aspect than a depletion of the surplus through the same cause. It may also occur that when a member is the owner of shares up to the limit which is allowed a single member, the conversion of surplus into capital will have the effect of giving to a member shares of stock in excess of the number which he is entitled to hold.

The third method leaves the question of surplus open except in so far as it is used as a basis for fixing the real value of shares in the old organization. Under this method a new organization would be formed with a capital stock and proposed surplus identical with that of the old, the effect being to make the true value of shares in the new organization an amount above par exactly identical with the value above par of the shares in the old organization. It would be necessary to place the value of shares to new members at a price above par value which would make their contribution to the surplus equal to that contributed by the old members, or in other words, equal to that which the old members would have received had the surplus been distributed as a cash dividend.

In point of fairness to the members of the old organization and safety to the new organization the last method would seem to be the best. The chief objection would be the difficulty of convincing members that book value or true value as measured by the surplus should form the basis of price rather than the par value which happens to be printed upon a stock certificate and which may as frequently appear on stock certificates representing stock of no value.

GENERAL SUGGESTIONS.

SELECTION OF PLANT.

The selection of the type of plant and the location involves two problems. The first and most difficult is that of deciding whether to purchase an existing elevator plant or to build a new one. It usually is considered advisable to purchase one of the local elevators if one is for sale and if it is found suitable for the purpose. The next problem is to proceed in such manner that an excessive price will not be placed upon the elevator which it is desired to purchase.

"Good will," which in certain commercial organizations is placed at high value, usually is of minor consideration to a cooperative association, because it depends principally upon a membership for patronage. This fact should be presented fairly and fully to the owners of the property under consideration, and an option of purchase should be secured from them. After a company has been formally organized and before any property is purchased the services of a reliable and disinterested consulting engineer should be secured to examine and appraise the property and to determine what repairs and improvements are necessary to make it entirely suitable and capable of efficient operation. The services of such a person are usually well worth the cost whether it is decided to buy or to build a plant. If it is decided to build, his services will be needed in checking the estimates and proposals of the different contractors who are invited to submit plans and bids. Not always can the proposal of

the lowest bidder be accepted as being the cheapest, and it is desirable to have some disinterested expert analyze the different proposals in detail and later to protect the interest of the association by seeing that the work is done according to contract terms. While the size and equipment of the plant must depend always upon local conditions, a smaller and better equipped plant is preferable to one larger and less efficiently equipped. It should be remembered that a large storage capacity may be desirable for certain purposes, but that with such a plant there is ever present the temptation to fill it. During periods when cars are difficult to obtain and the condition of grain is such that it can be stored on the farm more safely than in an elevator it is almost impossible for managers to refuse to receive grain while a storage space remains, and the chance for financial loss through deterioration is made the greater by having excessive storage capacity. An elevator which has a capacity of from 25,000 to 35,000 bushels, equipped in a modern manner, and which is capable of being emptied quickly when cars are available seems to be the plant generally favored by elevator companies which do not make a practice of storing grain for a storage charge. In the selection of a plant type it may be well to have in mind possible extensions and enlargements and to plan accordingly. Concrete construction offers stability and economy in insurance costs. On the other hand, wood and steel offer advantages when remodeling to meet change of conditions or when it becomes necessary to abandon and wreck the plant. The correct type can be determined only with reference to specific local conditions and requirements.

DIRECTORS.

The directors are responsible to the membership for the successful conduct of the affairs of the organization. The type of men selected for directors will have much to do with keeping the confidence and loyalty of the membership. They should possess keen business judgment, but in carrying out their duties they should be able to subordinate their private interests and to work for the welfare of the organization. Men with a reputation for honesty and for open-minded conservative judgment are to be preferred. They should, of course, be competent and should believe in the cooperative system.

MANAGER.

The most important duty which the directors will have to perform is the selection of a business manager. All personal preference must be laid aside, and the interests of the company as a whole be considered. The position of manager of a cooperative elevator company is a peculiarly difficult one; the individual members must be satisfied and at the same time the financial interests of the company con-

served. It requires a man with tact, with ability to appraise human nature, and with the rare faculty of being able to decide impersonally against individual members in matters of controversy without giving offense.

A manager must possess a high sense of duty regarding his own responsibility toward the company in addition to a keen understanding of the equitable relations to be maintained between the individual members. It is not difficult to please so long as one may compromise every difficulty that arises, but such a course means general satisfaction for a time, then financial disaster, for difficulties will present themselves which can not always be settled in favor of the individual member and against the company. A manager having previous experience in a farmers' elevator where the business of both buying and selling is conducted and the general accounts are kept under the direct supervision of the manager should be employed if possible. Many high-class men are to be found among the local agents of the so-called line elevators, but the experience of these men, which in the main consists of buying wholly in accordance with instructions from a central office, does not usually fit them to take the responsibility and initiative required of the manager of a cooperative grain elevator. He not only must buy and sell upon his own judgment but must have some knowledge of corporation accounting and be qualified to stand on his own feet in every emergency. A high type of business man with little or no experience in grain is to be preferred to an inexpensive type of man with much experience in the simple routine of weighing and dumping grain and of issuing checks in settlement. Before employing any one as manager the directors should check carefully his past record and should not rely too much upon letters of recommendation which may be in his possession. The farmers' elevator companies in the States of Illinois, Iowa, Kansas, Nebraska, Minnesota, North Dakota, South Dakota, Indiana, Ohio, Oklahoma, Colorado, Michigan, and Missouri now have State organizations,¹ the secretaries of which are in a position to render valuable assistance in locating managers for new companies and in furnishing reliable information concerning the personal records of men who claim to have had experience. The State agricultural colleges of a number of these States likewise are in a position to give assistance.

STOCK CERTIFICATES.

It is not necessary that stock certificates be ready to issue to the members at the time of the payment of their subscriptions, but an

¹ Generally designated as "Farmers' Grain Dealers Association" of a particular State. The secretaries are at present located in the different States as follows: Bloomington, Ill.; Fort Dodge, Iowa; Hutchinson, Kans.; Omaha, Nebr.; Benson, Minn.; Thompson, N. Dak.; Sioux Falls, S. Dak.; Wolcott, Ind.; Defiance, Ohio; Lambert, Okla.; Denver, Colo.; Pontiac, Mich., and Montgomery City, Mo.

ordinary receipt may be given instead, which receipt is taken up when regular stock certificates are issued. The plan of organization presented in this bulletin contemplates that certain by-law provisions shall be printed upon the stock certificate, and for this reason it may not be practicable to use the regular stock form usually carried by stationers. However, it may be possible to select a stock form on which the special provisions may be printed upon the back of the certificate by the local printer, in which case a reference to these provisions should be made upon the face of the certificate. Care should be exercised that these stock forms do not contain matter which vitiates or conflicts with the special provisions.

MAINTENANCE AGREEMENT.

Persons having a knowledge of the early struggles of farmers' elevators in the United States may wonder at the absence in the suggested form of by-laws presented in this bulletin of the so-called penalty clause, which at one time was regarded as of much importance. Men who are familiar with the real intent and purpose of the first use of this clause, which in its most simple form provided for the payment to the company of a charge of 1 or 2 cents per bushel for every bushel of grain which any member of the company should market through other agencies or dealers, state that the idea of a penalty was entirely foreign to its purpose and that it was intended only as a voluntary and mutual arrangement whereby, if it became apparent that outside dealers were paying more for grain than it actually was worth in order to discredit the cooperative company, each member would contribute to the support of his company in the manner provided and as long as these conditions existed. The members would then sell their grain to such outside dealers, making these dealers fall victim to their own competitive methods. It provided an equitable means for contributing to the support of the cooperative company during an emergency. Other companies copied the idea but lost sight of its real purpose and tried to make it a coercive means to compel patronage. Used in that way its presence in the by-laws has served only to antagonize the members, and, quite aside from the legal difficulties which are in the way of enforcing such a provision, it is believed to have outlived its general usefulness. The patronage dividends in a truly cooperative company should furnish every inducement necessary to secure the patronage of the members without coercive means.

In case it becomes necessary to meet conditions brought about by other dealers paying more for grain than it actually is worth in order to discredit the cooperative company, a direct personal appeal to the members, stating frankly existing conditions and probable

conditions in the absence of the cooperative company, would seem to be a better method. This might be followed by an attempt to protect and maintain the company in operation by means of a special contract arrangement. Companies that wish to incorporate into their by-laws a substitute for the so-called penalty clause may provide therein that each member upon uniting with the association shall sign and enter into a contract of the form presented in the Appendix of this bulletin. (Form No. 8.)

It is believed that such an agreement when signed by the members will be much more effective and will withstand legal objections to a much greater extent than will any liquidated damage or penalty clause which can be devised and incorporated into the by-laws. Unlike the usual penalty or liquidated damage clause, it does not rest upon any assumption of damage, but upon a tangible and valuable service which is sold to the member for a charge. The rate of charge varies with the kind of service rendered and is applied to all grain marketed by a member, with the exception, that upon grain sold to the association, the charge is included with the usual buying margin and is not applied separately.

EMERGENCY CAPITAL.

The means whereby emergency capital is being provided by many companies deserves some attention. Comparatively few organizations have sufficient capital to carry them over the periods of heavy marketing without having to resort to loans. This is especially true of the new company which has not had an opportunity to accumulate surplus funds. The capital required at such times often exceeds the corporate borrowing power. It is neither necessary nor always desirable that an organization should have sufficient capital of its own to meet these emergencies, but frequently directors are required to pledge their own personal credit for these loans, which manifestly is unfair. The directors in many cases are placed in the position of having exceeded their corporate authority, and in the event of financial difficulty might be placed in an embarrassing situation. Sometimes the more prosperous members are prevailed upon to postpone grain settlements until after the period of heavy movement. This is equally unfair, since they are then placed in the position of unsecured creditors and are thereby required to assume individual responsibilities and risks not shared by the membership as a whole. Emergency capital is necessitated by the business in its entirety and should be furnished by the entire membership. If each member can be induced to give his accommodation note for a just proportion of the emergency capital requirements, and such note be made available for the purpose of collateral security to support emergency loans

only, the responsibility to a great extent will be divided among the membership. A suggested form of loan note is presented in the Appendix. (Form No. 9.)

In some communities there is a deep-seated prejudice against the giving of notes for any purpose, and it may be difficult to secure from the members the individual loan notes here suggested. Where this condition exists it may be less difficult to get all of the members to sign one contract in common whereby each member guarantees the credit of the association up to and including some definite amount to be placed opposite his signature. For this purpose the form for a loan guaranty (No. 10) in the Appendix may be used.

SPECULATIVE TENDENCIES.

A weakness on the part of farmers' elevator organizations which possibly is responsible for more failures than all other causes combined is the lack of an effective safeguard against well-meaning speculation. Managers buy grain with a definite margin of profit in view. In many cases this margin is determined by bids or offers in hand on which grain may be sold. Between the time of purchase and the time when sale conveniently can be made, market changes take place which affect the bids or offers on which the purchase price was based. Should the effect of these changes be too narrow or liquidate the expected margin a temptation is presented to hold the grain for a reaction which may not come. Should the effect of market changes be to increase the visible margin, the manager may feel that the market trend is upward and be inclined to speculate with the excess margins in the hope of increasing them still further. Not infrequently the tendency upon the part of managers to speculate in this way is encouraged by directors in the organization who are glad to receive the benefits of successful speculation but who are not slow to shift responsibility when the manager is found on the losing side of the market.

Steps should be taken by members, directors, and managers to agree upon some definite policy, which policy should be strictly adhered to. If cars can not be secured with which to take care of time shipments and purchases can not safely be hedged, it is an inopportune time to permit purchased grain to accumulate in the elevator. The risk of loss through declining markets should not then be allowed to shift from the individual member to the organization. Grain should remain on the farm or in storage until such time as a price that is fair to the farmer can be fixed, and the handling charge can be definitely determined. The directors should be directly responsible for the preparation of a daily statement by the manager or bookkeeper which should be filed in the office of the company and

which should show the number of bushels of grain of each kind which is being carried unsold or oversold as the case may be. Failure of the manager to keep within a stipulated number of bushels long or short should be followed by dismissal. The province of a farmers' elevator is extensive, and its legitimate activities are many, but speculation, well-meaning or otherwise, is foreign to its intent and purpose and must be carefully guarded against if lasting and worth while success is to be attained.

APPENDIX.

NOTES TO FORMS.

No. 1. *Capital Stock Subscription Contract*.—This form is intended for use when capital-stock subscriptions are solicited prior to organization. After incorporation the stock-subscription contract may be in the following form:

"We, the undersigned, do apply for membership in [The ----- Grain Growers' Cooperative Association], a corporation organized and incorporated under the laws of the State of -----, having its principal office at -----, -----, and we hereby severally subscribe for and agree to take the number of shares of the capital stock of said corporation placed opposite our respective names at the par value of \$----- each, paying cash therefor upon demand."

No. 2. *Minutes of Members' First Meeting*.—This form is not intended to cover all of the matters which are to be acted upon at the first meeting, but will be useful only as a suggestion for the preparation of the blanket form of minutes referred to on page 23 of this bulletin.

No. 3. *Call and Waiver of Notice*.—This is the form also referred to on page 23 of this bulletin, and it should be signed by all of the incorporators pursuant to the first meeting of the stockholders.

No. 4. *Notice of Special Meeting of Members*.—This form needs no explanation further than that it must conform to the method of calling special meetings agreed upon in the by-laws, which in turn must be in compliance with statutory requirements.

No. 5. *Stock Certificate*.—Care must be taken that by-law provisions relating to the transfer of stock, limitation upon ownership, or other restrictions or reservations, which are printed upon the stock certificates are made to conform exactly with the by-laws as adopted.

No. 6. *Personal Guaranty of Indemnity on Issue of New Stock Certificate in Lieu of Lost Certificate*.—This form may be used when the person to whom a duplicate certificate is issued is fully responsible for any loss which may be incurred in consequence of two certificates for the same shares being outstanding at the same time.

No. 7. *Bond of Indemnity for Lost Certificate*.—This will be used when additional security is deemed necessary for possible loss growing out of the issuance of duplicate certificates of stock.

No. 8. *Service and Maintenance Agreement*.—This is referred to on page 30 of this bulletin as a substitute for the objectionable penalty clause sometimes used when it is desirable to provide against the possibility of members selling their products outside the association. Its use is recommended in special cases only and not as a part of the general operating plan for cooperative elevator companies.

No. 9. *Member's Emergency Loan Note*.—This is an ordinary demand note used by the association only as collateral to support loans required during emergency periods. It is in fact a means whereby the individual member loans his credit to the association for a limited amount. Upon withdrawal from membership the notes are, of course, returned to the maker.

No. 10. *Loan Guaranty*.—This form is suggested as a substitute for the loan note (Form No. 10) when it is found desirable to have all of the members sign the same instrument. In making changes in this form care must be taken that each individual member is not made jointly and severally liable with the cosigners for the full amount of the loan liability, or the purpose of the contract will be defeated.

Form No. 1.

CAPITAL STOCK SUBSCRIPTION CONTRACT.

We, the undersigned, for the purpose of forming a cooperative association at to be incorporated under the laws of the State of with an authorized capital of \$..... and to be known as [The Grain Growers' Cooperative Association] or by similar name, hereby severally promise and agree to become stockholders in a corporation hereafter to be organized and to take the number of shares of stock placed opposite our respective names at the par value of \$..... each, paying cash therefor upon demand when the corporation shall be organized and when at least \$..... shall have been subscribed.

Names.	Addresses.	Shares.	Amount.
.....			
.....			
.....			

Form No. 2.

MINUTES OF MEMBERS' FIRST MEETING.

Pursuant to a written call and waiver of notice signed by all of the incorporators, the first meeting of the stockholders and members of [The Grain Growers' Cooperative Association] was held at [here state time and place of meeting].

Meeting was called to order by and on motion by, was elected chairman, and was appointed secretary.

The secretary presented and read the call and waiver of notice, pursuant to which the meeting was held. On motion it was ordered to be entered in the Book of Minutes following these minutes:

The following persons were present: [Names of those present at the first meeting].

The chairman presented a [certified copy of the Certificate of Incorporation or Charter as the case may be] and stated that the original had been [here state time and place of filing or other procedure]. On motion it was ordered that same be entered on the first pages of the Book of Minutes.

The secretary presented a form of by-laws prepared and recommended by [committee or counsel], which was read article by article, and as a whole, unanimously adopted and ordered to be entered in the Book of Minutes immediately following the [Certificate of Incorporation or Charter].

Next was conducted the election of [seven] directors as provided for in the By-Laws, Messrs. and being first duly appointed inspectors of election. All the stockholders having voted by ballot cast in person, the inspectors reported results as follows:

FOR DIRECTOR.

Name.	Votes.
-----	-----
-----	-----
-----	-----
-----	-----
-----	-----
-----	-----
-----	-----

The above-named persons were thereupon declared to be duly elected directors of the association.
On motion duly made and seconded, the following resolutions were unanimously adopted: [Any special actions taken].
There being no further business the meeting was declared adjourned.

Chairman. *Secretary.*

In pursuance of the preceding minutes, the following forms are entered in the Book of Minutes: [Call of meeting, Certificate of Incorporation, By-Laws, etc.].

Secretary.

Form No. 3.

CALL AND WAIVER OF NOTICE FOR FIRST MEETING OF STOCKHOLDERS.

We, the undersigned, being all of the incorporators of [The ----- Grain Growers' Cooperative Association], a corporation organized under the laws of the State of -----, and all of the subscribers to the capital stock of the corporation entitled to notice, do hereby call the first meeting of stockholders to be held at -----, at ---- o'clock, on the ---- day of -----, 192--, for the purpose of accepting the charter, adopting by-laws, electing directors, [description of any other specific business to be transacted], and to consider and act upon all other business that may properly come before this meeting. We do hereby waive all requirements as to notice or publication of the time, place, and purposes of the first meeting and do consent to the transaction of any and all business pertaining to the affairs of this corporation.
Dated at ----- this ---- day -----, 192--.
[Signatures of incorporators]:

Form No. 4.

NOTICE OF SPECIAL MEETING OF MEMBERS.

-----, 192--.
Mr. -----,

DEAR SIR: You are hereby notified that pursuant to a call of the Board of Directors of [The ----- Grain Growers' Cooperative Association] a special meeting of the members of the Association will be held at [state exact time and specific place of meeting], for the purpose of [describe accurately the purpose of meeting], and for the transaction of any and all business in connection therewith which may properly come before said meeting.
Yours very truly,
-----,
Secretary.

Form No. 5.		STOCK CERTIFICATE.	
Certificate No.		[THE GRAIN GROWERS' COOPERATIVE ASSOCIATION] Par Value of	
for Shares		A Cooperative Company Shares\$..... Each	
Issued to		Incorporated under the laws of the State of	
Date.....		No.....	
Transferred from		Authorized capital \$.....	
Date.....		THIS CERTIFIES THAT	
Original Certificate Number.		[THE GRAIN GROWERS' COOPERATIVE ASSOCIATION]	
Number of Original Shares.		, fully paid and nonassessable, and is a member of said Association.	
Number of Shares Transferred.		, is the owner of	
In consideration of the issuance to me		Shares of the Capital Stock of	
of this certificate of stock No.		, election by the Board of Directors either	
for shares of the capital stock		to admit the holder to membership or to	
of [The Grain Growers' Cooperative		tender him the book value of such shares,	
Association] of		together with any dividends and refunds	
I do hereby agree to all of the conditions,		then due and unpaid."	
restrictions, limitations, and reservations		Article III. "Section 4. <i>Reversions</i> —	
stipulated in the By-Laws and amend-		If any member shall by purchase or by	
ments to the By-Laws of this Association		operation of law come into possession of	
and more specifically in Section 5 of Ar-		more than shares of the capital stock	
ticle II and sections 2, 3, and 4 of Article		of this Association, the Board of Directors	
III which are set out in full on the certi-		may elect to purchase such excess shares	
cate and made a part of this agreement. I		upon tender to him of the book value	
have received the said certificate of stock		thereof together with any dividends or	
this day of		refunds due and unpaid." Also in the	
....., 19.....		event of the death or disability of the	
Witness:		owner of any shares of stock in this	
Signature of Member.		Association such shares of stock shall	
.....		revert to the Association upon the	
.....		tender of payment by it to its heirs or	
.....		legal representative, the book value of	
.....		same, together with any dividends or	
.....		refunds due and unpaid, or it may elect	
.....		to transfer such shares to his heirs or	
.....		legal representatives —	
.....		all of which is made a part of the signed	
.....		agreement and receipt which appears on	
.....		the stub-record bearing the same num-	
.....		ber and date as this certificate.	
[SEAL.]		In WITNESS WHEREOF, the duly authorized officers of this cor-	
.....		poration have hereunto subscribed their names and caused the	
.....		corporate seal to be hereunto affixed this day	
.....		of A. D. 19.....	
.....		Secretary.	
.....		President.	

(Back of stock certificate.)

FOR VALUE RECEIVED hereby sell, transfer, and assign to

..... shares of stock within mentioned and hereby authorize

..... to make the necessary transfer on the books of the corporation.

Witness hand and seal this day of, 19....

Witnessed by:

CERTIFICATE
for Shares
of the
Capital Stock
of
[THE GRAIN GROWERS'
COOPERATIVE ASSO-
CIATION]
Issued to
Dated

Form No. 6.

PERSONAL GUARANTY OF INDEMNITY ON ISSUE OF NEW STOCK CERTIFICATE IN LIEU OF LOST CERTIFICATE.

To [The Grain Growers' Cooperative Association]:

In consideration of a duplicate certificate, numbered, for shares of the capital stock of the above-named Association, having this day been issued to me, in lieu of the certificate numbered for the same shares previously issued to and now owned by me, which has been lost [or, accidentally destroyed] by me, I hereby undertake to refund to and to indemnify the said Association against all costs and expenses and all loss which may be incurred by the said Association in consequence of two certificates for the same shares being outstanding at the same time.

Executed at, this day of, 19....

Form No. 7.

BOND OF INDEMNITY FOR LOST CERTIFICATE OF STOCK.

Know all men by these presents that we,, of, as principal, and, of, as surety, are held and firmly bound unto [The Grain Growers' Cooperative Association], a corporation organized under the laws of the State of, in the sum of dollars, to be paid to the said [The Grain Growers' Cooperative Association], its successors and assigns, for which payment well and truly to be made,

we bind ourselves, our heirs, executors, and administrators, firmly by these presents.

Sealed with our seals this _____ day of _____.

The condition of this obligation is such that:

Whereas, the said [principal] is the owner of record of _____ shares of the capital stock of the said Association, of the par value of [\$50.00] each, and has made application to the said Association for the issue of a new certificate for the said _____ shares of stock, alleging that the original certificate issued to him for said shares, numbered _____ and dated the _____ day of _____, is lost [or, destroyed]; and, whereas, the said Association has this day issued to the said _____ a new certificate for the said _____ shares of stock:

Now, if the said obligors shall at all times defend, save harmless, and indemnify the said [The _____ Grain Growers' Cooperative Association], its successors and assigns, from and against all claims, demands, and actions arising from or on account of the said original certificate, and against all damages, costs, and expenses by reason thereof, and shall deliver or cause to be delivered up to the said Association for cancellation the said original certificate if the same shall be found, then this obligation shall be void; otherwise it shall remain in full force.

[Signatures and seals]:

Form No. 8.

SERVICE AND MAINTENANCE AGREEMENT.

THIS AGREEMENT, made and entered into at _____ on this _____ day of _____, A. D. 19____, between [The _____ Grain Growers' Cooperative Association], a corporation organized and existing under the laws of the State of _____, having its principal place of business at _____, in said State, hereinafter called the Association, and _____ of _____ County, _____, hereinafter called the Grower, witnesseth:

THAT FOR AND IN CONSIDERATION—

1. That the Association shall establish, equip, and maintain an office and grain elevator at _____, _____, and there provide equipment, facilities, and means for weighing, grading, shipping, and handling wheat, corn, oats, and barley of different variety and grade.

2. That the Association shall there provide and have available to the Grower, market news and other information concerning the values and market condition of wheat, corn, oats, and barley, of different variety and grade, and shall furnish the same to the Grower on request.

3. That the Association shall there employ and have available to the Grower the services of an elevator Manager whose duty it shall be to secure and to furnish to the Grower upon request, in so far as it is practicable, all special market news, and other information and advice which the Grower may require relative to the marketing of grain and the procurement of seed grain.

4. That the Association shall weight and grade any and all grain of the kinds herein described, whether sold to or marketed through the Association, or to or through any other dealer or agency, which the Grower shall present for weighing and grading at the Association's office at _____, _____.

THE GROWER AGREES to pay the Association for such advantages, privileges, use, market news information, and weighing and grading service at the rate of [one cent] per bushel for each and every bushel of wheat, corn, oats, and barley which the Grower shall sell or market either directly or indirectly to or

through the Association or to or through any other dealer or agency during the life of this contract. Such charge shall become due and payable immediately upon the sale or delivery of any and all grain, but shall not be applied to any grain which the said Grower shall have grown or come into possession of in territory not tributary to the shipping points of the Association.

IT IS MUTUALLY AGREED that upon all grain which the Grower shall sell to the Association or which he shall require the Association to handle through its elevator and warehouse at -----, -----, the charge of [one cent] per bushel herein stipulated to be paid shall not be in addition to, but shall be a part of the whole charge or charges which may hereafter be established for elevation and loading and for other services and handling.

IT IS FURTHER AGREED that either party may terminate this contract on the first day of [July] of any year by giving notice in writing to the other party at least [ten] days prior to said date of the intent to so terminate. Termination shall then be effective on the said [first day of July], otherwise the contract shall continue in full force and effect so long as the Grower shall reside in territory tributary to the Association's office and shipping points, or shall continue to market any wheat, corn, oats, or barley in said territory.

IN WITNESS WHEREOF the said parties have executed these presents in duplicate the day and year first above written.

[The ----- Grain Growers' Cooperative Association.]

By -----,
President.
-----,
Grower.

Witness:

Form No. 9.

MEMBER'S EMERGENCY LOAN NOTE.

-----19-----
On demand, for value received, I promise to pay to [The ----- Grain Growers' Cooperative Association] or order, ----- Dollars \$----- without interest.

Payable at:

Form No. 10.

LOAN GUARANTY.

To ----- Bank:

In consideration of your having at our request agreed to advance to [The ----- Grain Growers' Cooperative Association] any sums of money it may require during the life of this contract, not to exceed at any one time the total amount guaranteed hereunder:

We, the undersigned members of [The ----- Grain Growers' Cooperative Association] hereby guarantee to you the repayment by the said [The ----- Grain Growers' Cooperative Association] of all sums of money

advanced by you to it as aforesaid, with interest at the rate of ---- per cent per annum, but subject to the limit on our aggregate and individual liability hereafter expressed.

1. This guaranty shall be a continuing guaranty, but our aggregate liability shall not under any circumstances exceed the sum of \$-----, and the proportionate share or liability of each of us individually in respect of the said sum shall not exceed in amount the sum placed opposite our respective signatures at the foot hereof.

2. Within the aforesaid limits of liability this guaranty shall extend and be applicable to the whole debt that shall ultimately be due to you from [The ----- Grain Growers' Cooperative Association] in respect to money advanced by you to it as aforesaid, and not merely to so much thereof as shall be co-extensive with our aforesaid maximum aggregate liability hereunder.

3. You shall be at liberty without discharging us from our liability hereunder to grant time or other indulgence to the said [The ----- Grain Growers' Cooperative Association] in respect to money advanced by you to it as aforesaid, and to accept payment from it in cash or by means of negotiable instruments, and to treat with it in all respects as though we are jointly liable with it as debtors to you instead of being merely sureties for the debtor.

4. In order to give full effect to the provisions of this guaranty we hereby waive and each of us hereby waives all suretyship and other rights inconsistent with such provisions and which we might otherwise be entitled to claim and enforce. We hereby waive and each of us hereby waives all notice respecting your acceptance of and assent to this guaranty and all notice necessary to charge us as guarantors hereunder.

5. Each guarantor shall be at liberty at any time to withdraw from all liability hereunder on payment to you of such sum as shall represent the proportion which his individual liability hereunder shall bear to the aggregate sum of advances made to [The ----- Grain Growers' Cooperative Association] and remaining unpaid at the time of his withdrawal. In the event of the death of any surety his personal representatives shall be at liberty to exercise a like power of withdrawal, and shall thereby relieve his estate from future liability under this guaranty.

Executed at -----, this ---- day of -----, 192-----

Signatures of Guarantors:

Amount Guaranteed:

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 861

Contribution from the Bureau of Markets
GEORGE LIVINGSTON, Chief



Washington, D. C.

September 13, 1920

MARKETING EASTERN GRAPES.

By DUDLEY ALLEMAN,
Assistant in Market Surveys.

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INTRODUCTION.

There are three main types of grapes produced in the United States, the European or *vinifera* type, grown extensively in California, among the principal representatives of which are the Tokay, Malaga, and Emperor; the *labrusca* type, grown in practically all sections of the country, represented by the Concord, the Niagara, and the Catawba; and the Muscadine grapes, grown in the South Atlantic and Gulf States, of which the oldest and best known variety is the Scuppernong. This bulletin deals with the marketing of *labrusca* grapes, known commercially as Eastern grapes; the European or Western grape and the Muscadines present very different problems of production and use.

HISTORY OF VARIETAL DEVELOPMENT.

When the first colonists reached eastern America they found the native grapes growing luxuriantly. As early as 1616 Lord Delaware wrote to England, "In every boske and hedge we have thousands of goodly vines running along and cleaving to every tree." These flourishing native species of grapes encouraged the importation of the best English and French varieties, which were planted in great number from New England to Florida. All of these vines sickened and died, but apparently only those planters immediately

involved were discouraged, for others were always ready to attempt the precarious experiment, hoping to find some more favored spot where these varieties would thrive. Such attempts to grow *vinifera*, or Old World varieties, in the eastern part of the United States were continued over a hundred years, and thousands of dollars were lost in the futile experiments. They served only to prove conclusively that *vinifera* varieties would not grow successfully in the East.

In the early part of the nineteenth century the American grapes, species indigenous to this country, such as *labrusca*, *aestivalis*, *rotundifolia*, and *riparia*, were brought under cultivation. Because of their already established resistance to phylloxera, which prevents the growth of *vinifera* in the East, these varieties for the most part flourished and were relatively productive. Until 1830 the common cultural practice was to transplant and cultivate promising wild vines. By this time three important varieties had been developed, the Catawba, the Scuppernong, and the Isabella. The first two were widely grown in the South and the Middle West and the latter in the North.

Shortly after the middle of the nineteenth century two important developments gave a great impetus to the grape industry. The first and most important was the discovery and dissemination of the Concord; and second was the extensive hybridization of American and European varieties.

Up to this time the only aim of grape growers and breeders was to obtain stock suitable for the manufacture of wine, but following the introduction of the Concord and other varieties of high quality the production of table stock began to assume an increasingly greater relative importance in the East, until in recent years the consumption of grapes by wineries has been smaller than the amounts sold as table stock and for unfermented grape juice.

THE RISE AND FALL OF COMMERCIAL PRODUCTION.

The grape industry grew rapidly during the two decades prior to 1880, but it was in the decade after 1880 that the greatest expansion occurred. In some sections grape growing was found so profitable that it assumed speculative proportions and many vineyards were planted in sections which were totally unsuited to grape growing. The decade 1889-1899 was a period of readjustment, a reduction in acreage taking place throughout the South and the Middle West, but this decrease was more than offset by large plantings in New York. Hence, the Twelfth Census showed the production in 1899 as 18 per cent above that of 1889. The next 10 years, 1899-1909, showed an almost negligible increase in production, but the process of readjustment was continued.

The Thirteenth Census, taken in 1909, showed a still further relocation of production. The decrease in acreage and production in the South and the Middle West continued and was particularly marked in the southern and central parts of Ohio and Pennsylvania. During this period the industry assumed approximately the present areas of production. Michigan, and, to a much smaller extent, Delaware, Missouri, New Jersey, and North Carolina, advanced to the position they hold in the industry to-day, while New York's production was practically stationary.

No official data are available as to the acreage or production at the present time or the changes that have taken place since 1909, but it is safe to say that the commercial acreage has been materially reduced since that year. This reduction has been most marked in New York, Ohio, and in the Missouri Valley. Not only has the acreage diminished, but, in the opinion of well-informed growers and factors, the production per acre in the leading commercial sections is by no means equal to that of the early days of the twentieth century.

Table 1 shows the carlot shipments of Eastern grapes as reported to the Bureau of Markets by the various railroads on which the shipments originated, and incidentally it discloses the effect of the severe winter 1917-18 upon the commercial production.

TABLE 1.—*Carlot shipments of Eastern grapes for 1916, 1917, 1918, and 1919, as reported by originating railroads.*

State.	1916	1917	1918	1919	State.	1916	1917	1918	1919
Arkansas.....	15	8	9	16	North Carolina.....	13	0	0	0
Delaware.....	34	69	39	13	Ohio.....	258	215	54	108
Idaho.....	0	6	4	3	Oregon.....	0	2	3	4
Iowa.....	143	86	68	156	Pennsylvania.....	1,012	827	367	1,013
Kansas.....	30	39	14	33	Tennessee.....	1	0	0	0
Michigan.....	1,849	3,667	1,637	3,795	Virginia.....	2	0	0	0
Missouri.....	37	33	26	43	Washington.....	30	36	59	61
Nebraska.....	113	8	2	12					
New Jersey.....	5	4	1	0					
New York.....	4,489	4,140	2,055	4,215	Total.....	8,031	9,140	4,338	9,472

CHANGES IN MARKET OUTLETS.

Not only has the relative importance of various districts changed materially during the last two decades, but the purpose for which the grapes are used in the different sections has also undergone an evolution, gradual but none the less marked. It has been mentioned that toward the end of the nineteenth century the use of grapes for eating purposes—for table stock—began to surpass the amounts used for wine. This tendency continued until about 1907-8, when production became so plentiful that even a combination of good packing, low prices, and intensive distribution could hardly suffice to dispose of the crop as table stock. It was about this time that the manufacture of grape products began to assume an increasingly greater

importance. These new products—unfermented grape juice, champagne, and sweet wines manufactured in bonded wineries, and home-manufactured sour red wines—created three new market outlets. The first two of these grape products were made almost exclusively of local stock, that is, of grapes produced within hauling distance of the factories; but the third outlet was a proposition requiring bulk shipment with deliveries made either in trays or in 12-quart Climax baskets.

The peak of the shipments of table stock was reached between 1907 and 1911. After the latter date an increasingly large amount of stock was used annually for beverages. These new outlets increased the consumptive demand and made it easier to dispose of the crop, but incidentally resulted in the lowering of the standard of pack in several of the leading sections. So much less labor is required to prepare stock for pressing than for shipment as table stock that more and more stock went to juice factories, wineries, and in bulk to cities which contained a large foreign population.

PRESENT COMMERCIAL OUTLOOK.

Prohibition legislation gave rise to serious problems, by closing some of the important outlets hitherto used. The character of the grape industry is rapidly changing. Readjustments and changes in usual channels of trade are being abruptly forced on the growers between one season and another that in the usual course of commercial evolution would cover a period of years. The danger for the future lies in the possibility of the excess of supply over demand, but this can be minimized by utilizing to the utmost every available legal outlet.

The grape-juice industry is in a thriving condition and the demand for its products has not been adequately supplied in the last few years. The grape-juice factories can be relied on to absorb a fairly large proportion of the stock formerly used for wine.

The commercial manufacture of grape jellies, jams, and conserves which is being rapidly developed may create a demand even greater than the unfermented-juice industry, and, as it expands, will undoubtedly furnish an outlet for a very large tonnage.

The table-stock trade is also capable of expansion. This is especially true in New England, in the Middle Atlantic States, and in the South. The Middle West is probably adequately supplied with table stock by Michigan shippers, who have kept in touch with this class of trade much better than have the shippers of New York, Pennsylvania, and Ohio. The table of destinations, given in the appendix, shows the wide distribution of Michigan stock and the relatively narrower distribution of New York shipments.

COMMERCIAL VARIETIES.

As the grape industry of the East is founded upon the improved varieties developed during the nineteenth century, a short description of the characteristics of the leading varieties, from the commercial point of view, is here given since, of the 700 varieties recognized by pomologists, 7 constitute the great bulk of the production, only those 7 varieties are here described.

THE CONCORD.

The Concord is preeminently the leading commercial variety of the eastern United States. It is an interesting fact that the development of the commercial grape industry has gone hand in hand with the introduction of this variety in the section. The characteristics that have made the Concord the undisputed leader among varieties are its extreme hardiness and high productivity under a wide range of soil and climatic conditions. The large quantities of Concord grapes that have been disposed of commercially during the past two decades have created a demand for blue or black grapes on the part of the consuming public analogous to the favor in which the red varieties of apples are held.

The clear, red juice of the Concord makes it the leading variety for the manufacture of grape juice, and several of the factories which produce the highest quality of product refuse any other variety. Large quantities were formerly used for the manufacture of sweet red wines, to which it gave a bright ruby color, a fruity flavor, and a fine body. The Concord may not be held in high esteem by a few connoisseurs, but it is regarded as the standard variety by the general consuming public. It withstands diseases and insect attacks, produces good, close, fair-sized bunches of medium-sized berries, and has a most attractive color and bloom. Its only weakness is that it is not so good a shipper as some other varieties, as it rapidly loses its flavor after picking and the berries soon shell and crack.

Not only does the total commercial production of the Concord far exceed that of any other variety, but it is the leader in practically every grape-growing district north of the Potomac River and east of the Rockies, particularly in the Chautauqua-Erie belt of New York and Pennsylvania, where it occupies 95 per cent of the commercial acreage. In the South it is not so popular, for the berries ripen unevenly, but even there it finds some favor for home consumption.

Certain other varieties, notably the Niagara and the Delaware, often command a slight premium over the Concord, but this does not disprove the leadership of this great blue variety, as these other kinds meet a special and limited demand which can consume only a relatively small quantity of stock at premium prices.

THE NIAGARA.

The Niagara is the leading white variety, but does not find much favor outside of New York State, where it is a leader in the Lake Ontario district, a relatively unimportant section. It has never attained great commercial popularity, because its quality is not high, and because of the difficulties surrounding its culture. This variety is very weak in the root, is subject to insect attack and subsequent winter injury, does not mature its wood well, and is often badly affected by fungus diseases.

In appearance the Niagara is a very showy grape, with large, well-formed bunches. The skin does not crack easily, but the berries' shell badly from the stem. It has to a marked degree the "foxy" taste so characteristic of the *labrusca* species, and for that reason finds high favor with a small part of the consuming public. This results in an active demand for small quantities of this variety, with usual price premiums over blue varieties, but if Niagaras appeared in the market in as large quantities as Concords, it is probable that the special demand would be oversupplied and the price decline lower than that held by standard blue grapes.

THE CATAWBA.

The Catawba is a red variety of high quality and attractiveness, and is probably the best keeper of the commercial grapes. It is widely distributed, being a leading grape in Ohio, New York, and the South-east. The late ripening of this variety, with its susceptibility to early frosts, prevents its wider dissemination. In only two sections of the North are Catawbas planted extensively—the Erie shore of Ohio and the Central Lake district of New York. The variety is at its best in the latter section, particularly on the banks of Lake Keuka, on land extending back to an altitude of 100 feet above the surface of the lake. It is a very attractive grape, the bunches being large, even, and compact. Its quality is high, though often impaired by premature picking. In the past it has been largely used for wine, as it makes a good, light-colored vintage, which was often used as a basis for champagne. As a matter of fact, the American champagne industry was largely built upon this variety. Prohibition legislation released large quantities of Catawba stock hitherto used by wineries, but it is coming into favor for the manufacture of white grape juice, and much larger amounts than formerly will probably be consumed for this purpose.

As the Catawba is in only fair demand for table stock in most markets, and as the juice factories do not seem to be able to use all the stock formerly used for wine, this variety will probably appear

in greater supply on consuming markets in the coming years. This prospective increase in supply will probably eliminate the premium often received for this variety, but its many good qualities will undoubtedly soon create a demand that will prevent its price levels from dropping far below standard blue varieties, particularly late in the season, when demand has become well-established and supplies of other varieties are declining. Care should be taken by all interested in the handling of this variety not to hurt its popularity by shipping stock which has not fully matured. Generally speaking, the red varieties are relatively more popular in the South than they are in the northern markets.

The Catawba is one of the oldest commercial varieties, having been introduced and planted widely in the early part of the nineteenth century. Up to the time of the introduction of the Concord it was the leading commercial variety.

THE DELAWARE.

The Delaware is the standard of quality among the Eastern grapes. There is no variety even of the *vinifera* type of richer or more delicious flavor or with more agreeable bouquet than the Delaware. It flourishes under a wide range of soil and climatic conditions and finds favor throughout the eastern United States. Its wider commercial production has been prevented by its comparatively low yield, which is caused by the small size of the vine, slowness of growth, the small size of the berries, and the susceptibility of the foliage to mildew.

It is in active demand in leading terminal markets, generally commanding a marked premium over blue varieties. As this premium is not due to any special class demand, but rather to general excellence of the fruit of this variety, it is doubtful if larger supplies upon the market would greatly depress its relative price.

The Delaware is probably the most widely distributed of Eastern commercial varieties, as it finds favor in the Central Lakes and the Hudson River districts of New York, in Michigan, in Delaware, and is coming into commercial favor in the South as an early grape to ship to northern markets.

THE MOORE.

The variety known generally as the Moore is, in effect, an early Concord and is regarded in trade channels in that light. It resembles the Concord very closely, but the bunches are generally smaller, the individual berries larger, and the quality and texture not quite so good. It is not so hardy as the Concord and does not succeed on such a variety of soils, but it is a good keeper and shipper,

and having the advantage of ripening from two to three weeks before the Concord it may be regarded as a valuable commercial sort. Though less adaptable than the Concord in the matter of soils, it stands a much wider range of climatic conditions, thriving in New York, Michigan, the Missouri Valley, New Jersey, and the Southeast.

THE WORDEN.

The Worden is similar to the Moore in fruit characteristics, season, and soil requirements, and is rather more hardy and productive. If it were a better shipper it would probably largely replace that variety for the early trade. Its great drawback is tenderness of skin, which results in cracking and speedy deterioration. In addition, it ripens unevenly and sometimes two or three pickings are necessary for a high-class pack. Like the Moore, it grows well in New York, Michigan, the Missouri Valley, and the Southeast. Also like the Moore, it is regarded by the trade and by the consuming public as an early Concord. It is a valuable variety for local consumption and near-by shipment and finds some favor for grape-juice manufacture, particularly in the Chautauqua-Erie belt.

THE CHAMPION.

The Champion is an early blue variety that belongs to the same category as the Moore and the Worden in that it is sold upon the reputation of the Concord. In this case the Concord is hurt by the substitution, as the Champion is of poor quality, with a sour and rather disagreeable taste. It is an important variety for the lighter soils of Michigan, but does not assume commercial importance in other leading districts. Its low quality usually results in reduced demand, and it commonly sells from 1 to 5 cents below the Worden, the Moore, and the Concord, the usual discount being 2 to 3 cents on a 4-quart basket.

VARIETIES UNIMPORTANT COMMERCIALLY.

There are hundreds of other American varieties widely grown in a small way, but their commercial importance is slight. It is safe to assume that 95 per cent of the stock shipped to terminal markets belongs to the 7 varieties named above. Offerings of the varieties named below sometimes appear in the larger jobbing markets, but rarely in car-lot quantities, and are usually sold merely as blue, red, or white varieties. The more important of these white or green varieties are the Diamond, Dutchess, Elvira, Pocklington, Norton, and Winchell; of the red varieties, the Agawam, Brighton, Diana,

Goethe, Lindley, Virgennes, Ulster, and Wyoming; and of the blue or black varieties, the Campbell, Clinton, Cynthiana, Ives, Isabella, North, and Wilder. Of these, the Duchess, the Elvira, the Ives, the Norton, and the Cynthiana were used largely for wine, and it is questionable whether the continued production of these varieties will be found profitable, on account of the various commercial weaknesses each one possesses. The Ives, however, has been successfully used for the manufacture of grape juice, and this market outlet may be further developed for this variety.

METHODS OF PREPARATION FOR MARKET.

The changes forced upon the grape industry by recent legislation necessitate the most careful and businesslike handling of the crop. Astonishingly large numbers of growers and shippers are entirely unacquainted with methods and channels of distribution employed in other sections. Accordingly, this study and report have been made on comprehensive lines.

PICKING.

In picking, the bunches are cut from the vines with short, sharp spring scissors or grape shears and are laid in the tray or picking basket. This tray is usually placed on a low stool which is carried along the rows. The stool makes for efficiency and higher quality, as it is unnecessary for the picker to bend over each time a bunch is placed and the damage to the fruit which would result from carelessness in throwing or dropping the bunches into the container is avoided. When full, the trays or baskets in which the fruit is picked are placed in the row under the vines to be collected later. Stone boats or narrow double-turn wagons are used to collect the full containers and carry them to the packing house or station.

TRIMMING AND PACKING.

For a high-class pack some trimming is usually found necessary to remove defective berries. Although the fruit is seldom affected by insect pests, in some sections the second brood of larvæ of the grape-berry moth feeds on the inside of the berry, resulting in a shrunk condition or in so-called "wormy" grapes, which at times cause serious damage but of a kind which does not spread. The black rot often destroys many berries in a cluster and sometimes the entire cluster, while infection by the powdery mildew may destroy the marketability of individual berries or whole bunches. Also, in

some varieties, small unripened berries are found at picking time, and sometimes some of the berries in a bunch, especially those at the shoulder, are so tender as to crack or shell at picking.

FIELD OR PACKING-HOUSE TRIMMING.

Trimming may be done as the grapes are picked, in which case they are packed directly into the final container, or the grapes may be hauled to the packing house in trays and there trimmed and packed. The advantage of packing in the field is one of convenience, for the resultant pack is usually one of relatively low quality, as many defective berries are overlooked; also short measure is likely to occur in field packing. The principal cause is the shrinkage of the fruit after leaving the vine. The disadvantages of trimming and filling in the packing house are the added expense and the mechanical injury often caused by the additional handling, which may be minimized, however, by careful methods. It is generally believed that the resultant pack is usually of a higher quality than if done in the vineyard. The careful trimming made necessary by any serious damage, either by insects or disease, can best be done in the packing house. Many grapes from the Central Lakes and the Hudson River Valley districts of New York receive this extra attention, but in the Chautauqua-Erie belt insect and fungus injury are so light that a very good quality can be packed in the field by a moderately careful picker.

Central packing houses have been operated in a few instances, but without great success, due to various factors, such as extreme perishability of the product, the difficulty of securing sufficient skilled labor, and the high overhead cost of a packing plant for the short period of use.

GRADES.

No standard grades of grapes, as such, have been adopted, but certain cooperative associations and individual shippers have established reputations for high quality and good pack and receive a premium for their stock, which is marked by attractive labels pasted on the cover of the baskets in which their grapes are shipped. Two and 4 quart baskets may be labeled or branded in this manner, but 12-quart baskets not so conveniently. Branded stock receives a premium of from 1 to 4 cents over unbranded, generally about 1 to 1½ cents on 2-quart baskets and 2 to 2½ cents on 4-quart baskets.

CONTAINERS.

Wooden veneer baskets, of the Climax type, have been adopted as the standard package for table stock, in 2, 4 and 12 quart sizes, dimensions prescribed by Federal statute in 1916. Before this law

went into effect, the irregularities of the packages in use were detrimental to the industry.¹

The tray, or lug box, has been one of the most-used containers, but its popularity is on the wane. As it is a low, narrow, open, rough box, holding 25 to 35 pounds of fruit, it is a very satisfactory container for use in the vineyard, when fruit is picked into it direct from the vines. The tray is in general use for bulk shipments. However, for any market where the appearance and condition of the fruit affects its sale, this package should never be used, as it is unattractive in appearance and often brings the fruit to market in a bruised condition.

The "gift case" is an important container on the New York market, but is seldom used outside of the Hudson River Valley. It is a small case or crate containing eight 2-quart baskets, separated into 2 tiers of 4 each. The grapes are covered with white transparent paper, and the tiers are separated by a thin board. After the contents are disposed of this case is not returned, and the name "gift case" was adopted to distinguish it from the tray or lug, which is called "return crate" on this market.

Practically all long-distance shipments are made in Climax baskets, but in most of the large markets of the country local grapes may be found, which have been either hauled to market or shipped in less than carload lots, in almost every conceivable type of container.

Market baskets are of three general kinds—the diamond weave, the square weave, and the veneer. As a class they rank next in importance after the Climax type. The sizes are very numerous, 8, 9, 10, 11, 12, 13, 14, 15, and a few 16 quart baskets being found. The 8-quart or quarter-bushel basket, the 14 and 15 quart or short 2-peck basket (half-bushel basket), and the short one-third bushel basket, holding between 10 and 11 quarts, are found most frequently. It

¹As the Climax baskets are of so much importance to the industry in the East the following paragraphs are quoted from the standard container Act (39 U. S. Statutes at Large, p. 673). See also United States Department of Agriculture, Office of Secretary Circular No. 76: Rules and Regulations * * * under the United States standard container Act of August 31, 1916.

(a) The standard two-quart Climax basket shall be of the following dimensions: Length of bottom piece, nine and one-half inches; width of bottom piece, three and one-half inches; thickness of bottom piece, three-eighths of an inch; height of basket, three and seven-eighths inches, outside measurement; top of basket, length eleven inches and width five inches, outside measurement. Basket to have a cover five by eleven inches, when a cover is used.

(b) The standard four-quart Climax basket shall be of the following dimensions: Length of bottom piece, twelve inches; width of bottom piece, four and one-half inches; thickness of bottom piece, three-eighths of an inch; height of basket, four and eleven-sixteenths inches, outside measurements; top of basket, length fourteen inches, width six and one-fourth inches, outside measurement. Basket to have cover six and one-fourth inches by fourteen inches, when cover is used.

(c) The standard twelve-quart Climax basket shall be of the following dimensions: Length of bottom piece, sixteen inches; width of bottom piece, six and one-half inches; thickness of bottom piece, seven-sixteenths of an inch; height of basket, seven and one-sixteenth inches, outside measurements; top of basket, length nineteen inches, width nine inches, outside measurements. Basket to have cover nine inches by nineteen inches, when cover is used.

is an interesting fact that many baskets which sell for 1 peck are a trifle large, and almost all selling for 2 pecks are considerably short measure; thus it is well for the consumer to buy two 1-peck baskets when he can do so at the price of a 2-peck basket. To avoid prosecution, city dealers should be careful not to sell such short-measure packages as standard sizes of the containers they represent.

A container for fancy stock, known as the Delaware eight-basket carrier, is being used to some extent in Delaware, New Jersey, and in the vicinity of Philadelphia. It is a slat crate composed of two layers of 2-quart till baskets in layers of 4 baskets each, and is similiar to the Georgia peach carrier.



FIG. 1.—Loading cars in producing sections.

CAR LOADING.²

The improper car loading of grapes shipped to market is a most potent cause of loss. For all types of packages the "straight system," with all the packages placed end to end, extending from one ice bunker to the other, has been found most satisfactory. In every alternate layer of Climax baskets it is necessary to load those that touch one bulkhead crosswise in the car, in order to fill in the otherwise vacant spaces, but under no consideration should this be permitted elsewhere in the load.

² See Bird, H. S., and Grimes, A. M. Loading American Grapes. U. S. Department of Agriculture, Markets Document 14, 1918.

All slack should be taken up as the packages are loaded with racks to fill out at the end of the car when there is a surplus space. Every fraction of an inch of surplus space from side to side of the car should be tightly filled in by loading the last row diagonally and mismatching or "nesting" each row upon the one below.

"Mixed loads," or loads made up of different sizes of Climax baskets, or of a combination of baskets and trays, should be avoided. When absolutely necessary to ship mixed loads in order to assemble a full car, the one rule is to make completed rows of each kind of package from end to end of the car.

THE COMPLEXITY OF THE MARKETING MACHINERY.

The problem of marketing, in its final analysis, consists of the disposition by the producer of a product, of which he has more than he requires, to the consumer, who has not as much as he desires. This is fundamentally true of all trade. A simple sale from the producer to consumer is seldom possible, because of complicating factors.

The functions of the much-criticized middlemen, distributors, jobbers, and retailers have made possible the present high development of the commercial grape industry, for taken as a whole they form the agency through which the farmers' grapes are marketed. As it is much cheaper and more satisfactory, and as it permits wider distribution, the practice of shipping grapes in carlot quantities has been developed. This has led to the creation of yet another type of middleman, the local dealer and carlot assembler, who either buys outright from the producer or acts as his agent in disposing of his product.

Undoubtedly sharp practices and inefficient methods have been, and to some extent still are, in use by some middlemen, which work to the manifest disadvantage of both the grower and the consumer; but generally the methods and channels of marketing grapes have become so well-developed and standardized, and competition has so far eliminated dishonest dealers and inefficient methods, that the grape industry of the East is in a very good condition, in so far as distribution is concerned.

THE USUAL CHANNELS OF TRADE.

The methods used in different localities vary with local conditions, but any or all of the following methods may be applicable. A farmer with a small quantity of grapes to dispose of has the advantage in sections where the production is small; while a grower of large quantities has the advantage in one of the so-called grape sec-

tions, where surplus of production over local demand necessitates shipment to distant markets.

Grapes usually move successively from the grower to the local carlot assembler (local buyer or cooperative association), to carlot distributor (sometimes), to city carlot receiver, to jobber, to retailer, and then to consumer. Of course, there are many short cuts and variations to this method which have been worked out to meet individual conditions and requirements. It may seem cumbersome and inefficient to pass the fruit through so many hands, but when it is considered that sometimes the grapes of 50 or 60 growers are included in a car which may be shipped a great distance, perhaps as far as from New York to Colorado, or from Michigan to Texas, and that often the contents of the car go to over 2,000 different ultimate consumers, the difficulties of the problem and the need for specialization by the handlers are apparent. If division of labor and specialization are commended in manufacturing plants, should they be condemned in the grape industry?

SALES BY GROWERS DIRECT TO LOCAL CONSUMERS.

The simplest method of sale, that of producer direct to consumer, though open to all growers and to a limited extent practiced in all sections, is not of great commercial importance, and the larger the production of grapes in a section, the smaller is the relative importance which this method assumes. Farmers with small vineyards in a nongrape-producing locality often find a ready market among their neighbors, or they may haul their product to neighboring towns and villages and there peddle their crop. While the method is relatively unimportant, the quantity of grapes disposed of by this method in portions of the South, the Middle West, New England, and the North Atlantic States, outside of the specialized areas of grape production, is fairly large in the aggregate. The proportion of the consumer's dollar received by the farmer by this method may seem large, but it should be borne in mind that he has performed the functions of distributor, transportation company, jobber, and retailer, and is receiving payment for these services.

SALES IN SMALL LOTS BY GROWERS TO NEIGHBORING CITY CONSUMERS.

A second method is the direct sale by growers to consumers in neighboring cities and towns by express and parcel-post shipments. This has the general advantages and disadvantages of the former method and requires the services of less people in the distribution, but requires higher transportation charges than carlot shipments and necessarily reduces the possible marketing area. Also, as in the former case, this method is not feasible for large vineyards. The growth

of this method is hindered by the difficulty of getting in touch with consumers and of making collections, and by the fact that most city consumers desire grapes in lots of one or two baskets on short notice. The aggregate quantity thus sold is small, but the method has a wide application.

The recent great interest on the part of urban dwellers in the subject of marketing has led to the formation of many consumers' cooperative associations or buying clubs, which should present a profitable field for development to growers with small acreage.

It should be borne in mind in all of the sales direct to the consumer that the prices generally should not be so high as the retail price, for the consumers' ability to purchase stock in just the quantities he desires and just when he desires them, is one of the services figured into the retail price. A fair price for the farmer to charge the consumer for such sales would be the price at which the same stock sold to retailers in large near-by markets. Thus the producer receives payment which represents not only the cost of his product but the costs and profits of the buyer, carlot distributor, and jobber, and the consumer saves what would represent the cost and profit of the retailer on similar transactions. If a farmer ships in this manner direct to consumers, basing his charge on f. o. b. prices, he has a right to ask more than the regular current price to reimburse him for his extra trouble and knowledge of marketing conditions. When he peddles his products he has a right to charge the full retail price, but as he usually wishes to make quick sales, he may find it expedient to ask a slightly lower price.

SALES BY GROWERS IN PUBLIC MARKETS.

Grape growers near the larger cities sometimes find it to their advantage to haul their stock to the public markets, where they may sell direct to the consumer or to retailers at current market prices.

SALES BY GROWERS IN SMALL LOTS DIRECT TO RETAILERS.

Growers sometimes find it to their advantage to sell direct to retailers located in neighboring towns and villages. Such a trade can be made profitable by an energetic producer, who, in years of crop shortage, can generally obtain stock from his neighbors and in years of heavy production can dispose of his surplus through other channels. The disadvantages of this method of sale are numerous, the field of distribution is reduced by the necessity of less than carlot shipments, the freedom of the retailer in buying only for his requirements is reduced, and the uncertainty of less than carload

shipments is added. The costs and profits of the buyer, car-lot distributor, and the jobber are eliminated, and this saving should be shared between the farmer and the retailer to make this method satisfactory and profitable to all concerned.

SHIPMENTS ON CONSIGNMENT.

By far the most common method practiced by farmers who ship their own grapes is to consign to commission houses or brokers, who in turn sell to jobbers or sometimes direct to retailers. These factors act as the agent of the shipper, disposing of the grapes at the highest price obtainable, paying transportation, icing, and drayage charges, deducting a certain rate as commission, and remitting the



FIG. 2.—Icing cars in a large distributing center.

balance to the shipper. In some cities, such as Washington, D. C., and Columbus, Ohio, the functions of these various factors are not always distinct, as some houses perform the duties of car-lot receiver, commission merchant, broker, and wholesaler. The commission charge ranges from 5 to 15 per cent on the gross sales, but is usually between 7 and 10 on large quantities. An understanding should be reached beforehand as to exact percentage of commission to be charged.

Growers who have sufficient acreage to enable them to ship in car-load lots have a great advantage in this method of sale over growers who are forced to ship in less than carload lots, as the transportation costs are much less, temporary refrigeration while in transit (icing) is practicable, and the shipper has a much wider field of action, for he is able to forward his product to almost any market desired, either by direct billing or by diversion. By this method the farmer saves

the costs and profits of the local carlot assembler, whose functions he has himself assumed. It should be remembered, however, that the business of growing grapes and the business of marketing grapes are as different and distinct as the business of manufacturing agricultural implements and the business of running a rural hardware store. The fact that a farmer is able to produce grapes of high quality in abundance is no sure indication of his ability to dispose of them at a profit, and he should not attempt to enter this highly specialized field without a very clear understanding of the methods to be followed and an intimate knowledge of the demands and requirements of the various markets.

Unfortunately very unbusinesslike methods of consignment are employed by many growers who ship their products indiscriminately to the nearest large market whenever they happen to be ready to pick, without any study of the existing conditions on that market, or even a notification to their agent of their intention to ship.

OVERLOADING MARKETS.

Every market has a definite limit to its daily consuming capacity. When the carlot receivers or jobbers on any market find that the supplies of grapes on hand do not meet the demand, they naturally take steps to purchase them at the nearest producing section where the desired varieties and quality may be profitably obtained. On the other hand, if city dealers have several cars a day rolling toward their market, and in addition to these several shippers forward cars unsold to the same market, and they all arrive together, with perhaps heavy arrivals of freight and express less-than-carload shipments, it is probable that these arrivals will exceed the demand, and there will be a decline in price. Moreover, any continued surplusage of supplies will clog the channels of trade and result in severe loss to all concerned. Shippers should study the receipts on all markets to which they intend to ship and avoid those that are congested. In addition, when they ship on consignment, they should write or telegraph to their dealers giving date of shipment, number and size of packages, varieties included, and a fair statement as to the quality and condition of the shipment. When shipping in carlot quantities, they should also specify car number and initials and should forward the bill of lading.

CONSIGNMENT DECLINING.

Principally on account of the difficulties mentioned above, the straight commission-house business in the grape industry seems to be on the decline. Many city dealers prefer the more businesslike method of purchasing outright in the producing sections the stock they need. In sections of large acreage, where marketing methods

have become standardized, growers who consign their stock in normal years are less often found, and it is only in the outlying and scattered districts, in sections from which the shipments are small, that consignment is now the standard practice. It should not be overlooked, however, that in a generally weak market consignment may be the only alternative.

CONTRACT SALES.

Sales on contract, or outright sales, are sometimes made. Such sales are the result of an individual contract, which varies greatly in its adaptation to local conditions and is the result of bargaining between the grower and the buyer, who may be a consumer, such as a grape-juice factory, or a city carlot receiver or a local buyer. Most of such sales are made on the basis of cash on delivery and are contracted for before the picking season. With the exception of sales to juice factories, this method of sale is seldom found in leading commercial sections, but is confined to outlying vineyards where growers are not well in touch with market prices and conditions. A notable exception is the Keuka Lake district of New York, where most of the growers sell on contract to local dealers well in advance of the harvesting season.

SALES TO LOCAL BUYERS OR CAR-LOT ASSEMBLERS.

The most common method of sale is to local buyers or car-lot assemblers at the current market price. Where grapes are produced commercially there are generally several dealers who make a specialty of buying for cash the crop of the growers in their locality, usually delivered to the car. Here they assemble them in carloads and dispose of them through any of the usual market outlets. This is the simplest and easiest method of sale for the grower, as it transfers the highly specialized business of marketing the crop to a man who has had relatively wide experience. Besides his other duties the local carlot assembler often assumes large financial risks. The grower should also expect to pay him for his specialized knowledge of the industry.

Conscience and competition usually keep down the profit of the local buyer to reasonable figures. In the sections of large acreage, such as parts of New York and Michigan, the competition between buyers is usually so keen that the grower is assured of the full market price for his product. However, in the more isolated sections, abuses have crept into the system and individuals are often found who absolutely control their limited districts, buying grapes not on the basis of what they are worth at the current market price, but on the basis of the lowest price at which they can be obtained.

Such abuses are usually founded upon the growers' ignorance of marketing conditions and their failure to interest outside competition. Publicity, which informs dealers in other sections of the local conditions and induces them to enter the deal, often provides the necessary competition. Cooperation between the growers to perform themselves, and for their own profit, the functions of the local buyer, is another alternative.

Conditions are seldom improved by individual growers entering the field of marketing and trying to compete with the buyer, for in few such cases is the acreage controlled by any grower sufficient to enable him to ship easily in carload lots and the necessary connections with the trade in large terminal markets usually are lacking. Too often the power of monopolistic local buyers is strengthened by the failures of growers who have attempted to break away and enter the field of marketing.

Most local buyers or carlot assemblers try to dispose of their stock to city carlot receivers on shipping-point basis, as the speculative features of their business are thereby reduced to a minimum. When their reputation for financial soundness and integrity has been established they are usually successful. This type of factor may dispose of his crop in any of the numerous ways which are also open to the grower—on consignment, to traveling city buyers through exchanges, to juice factories, etc.

In a few cases carlot assemblers at shipping points have developed businesses similar in their methods to cooperative marketing associations, in that they handle the product of some of the growers in their locality, acting merely as an agent and making a certain fixed charge per package. An example of this method is to be found at North East, Pa.

SALES THROUGH COOPERATIVE ASSOCIATIONS.³

In many of the more important sections grape growers have taken advantage of the possibilities of collective action by the formation of cooperative associations. Cooperation is the act of working with others for a common benefit, and in marketing fruit it is most practical in its application to crops of which a few standard varieties ripen at the same time. Thus it has proved of great value in the grape industry.

As these associations take charge of the marketing of the grapes produced by their members, they perform a function in the industry quite analagous to that of the local buyer or car-lot assembler. The associations generally receive the grapes at the car door, load them

³ See Bassett, C. E.; Moomaw, C. W.; and Kerr, W. H. Cooperative Marketing and Financing of Marketing Associations. In Yearbook U. S. Department of Agriculture, 1914.

in the car, inspect their quality, and sell them for the highest price obtainable. The grower usually allows the association to take full charge of the shipment, and payment is commonly made by pooling the returns of the shipment of each day and remitting to the growers in proportion to their haulings of the various sizes and varieties, after deducting a certain charge for expenses. The details of these business arrangements, which depend on the constitutions and by-laws of the various organizations, cover a wide range of conditions and are generally covered by a contract between the association and each of its individual members. In some cases growers are allowed entire freedom of action, in that they may market their crops through the associations or through outside agencies, as they see fit; in others they are obligated to allow the association to handle all of their crops. Some associations charge their members on a percentage commission basis; sometimes they make a fixed charge per basket or per ton, out of which the expenses of management must be borne. The profits, if any, at the end of the shipping season are divided among the shareholders of the association or prorated among the shippers, according to the rules of each association.

Most cooperative associations in the grape industry endeavor to sell at the loading station. Other methods, such as consignment and sales to juice factories, are practiced, but the great bulk of the stock is sold on telegraphic orders.

Notable examples of cooperative grape shipping associations are to be found in the leading sections of Michigan, New York, and the Missouri Valley. While cooperation solves many problems, it will surely result in failure unless the two basic requirements are met: (1) Such an organization must be founded on some definite urgent need, and (2) the manager or director of such an enterprise must possess the requisite ability and knowledge of marketing conditions.

SALES TO GRAPE-JUICE FACTORIES.

The tremendous growth of the unfermented grape-juice industry during the past few years has established a most satisfactory market outlet for those growers whose vineyards are in close proximity to such factories. A large proportion of the tonnage produced in the Chautauqua-Erie belt, in Michigan, and in the Hudson River Valley is consumed in the manufacture of this product, and in the first district named nearly as much stock is consumed locally by factories as is shipped to outside points.

The problems of marketing are reduced to a minimum for those growers who sell to juice factories. To some extent, both in Michigan and in New York, factories purchase their requirements from neighboring growers under contracts made before the grapes mature,

which specify definitely the price to be paid, but the common method of sale is a contract to purchase the grower's entire crop at the market price prevailing on the day of delivery.

Confusion sometimes arises as to just what the market price is, particularly when the consumption by juice factories is so great that few bulk grapes are sold for outside shipment. This occurred in Michigan in 1918 and to a less extent at the beginning of the season of 1918 in the Chautauqua-Erie belt. As no ratio between the price of 4-quart baskets and that of stock shipped in 12-quart baskets or trays has ever been established, it is usually left to the juice factories to pay what they think proper. Such situations are unfortunate, as they furnish a chance for unfair practices, but in the main the leaders of the grape-juice industry have the interests of the grower at heart and may be relied on to pay a fair price for what they buy. A still more effective insurance of a fair return to the grower is the fact that the production of grape juice has not of late years equaled the trade requirements. This has caused a very healthy competition between the various factories for the products of the vineyardist.

Most of the grapes used by juice factories are produced within hauling distance, but in 1918, on account of the short crop, much stock was received by shipment, both by short hauls from within the same district and by long hauls, as between Michigan and Westfield, N. Y., and between Chautauqua County and Highland, N. Y.

The common grape trays, usually owned by the factory, are the standard package for grape-juice stock, though 12-quart Climax baskets are often employed, into which grapes are picked directly from the vines. Sales of stock in baskets are generally made on the basis of the gross weight; that is, with the baskets included.

While juice factories generally prefer to buy from the grower, they do not confine their purchases to this source, but sometimes send out representatives, who buy from local dealers or cooperative associations or purchase stock on telegraphic orders. Growers in outlying sections who are able to ship in carload quantities would do well to investigate the possibilities of this method of sale. On account of its acidity, the Concord comprises the great bulk of the grape-juice stock, but the Worden is sometimes used, and the Clinton is recommended as a valuable variety for this purpose.

FREE-ON-BOARD SALES.

In the early days of the grape-shipping industry, sales were made almost exclusively at the point of destination. Of late years the tendency has been toward the other extreme, until the great bulk of shipments from the more important grape-growing sections are now sold f. o. b. point of origin.

"F. o. b." is an abbreviation of the phrase "free on board," which means loaded in the car, ready for shipment, with no attachments to the stock. From the definition it will be seen that a car may as well be f. o. b. Kansas City, Mo., as f. o. b. Lawton, Mich., and so, while this phrase is used almost without exception in this industry as referring to shipping points, the exact station where cars are loaded should be specified in all cases.

Sales made on an f. o. b. basis imply contracts, either written or understood, between the shipper and the buyer, which cover a wide variety of clauses and conditions, but which have been standardized into three general types: Carloads f. o. b. usual terms; carloads f. o. b. cash track; and joint or open account sales. The volume of less than carload shipments of grapes is so small that carloads are regarded as the unit.

CARLOADS F. O. B. USUAL TERMS.

The great majority of the Michigan crop is sold on the basis of "f. o. b. usual terms," and this type of trade has reached a high stage of development in Berrien and Van Buren Counties.

The shippers in this section, who are for the most part brokers and cooperative associations, keep in close touch with all possible market outlets, sending out daily quotations by wire to any available consuming center where they think they can place a car. Whenever one of these bids is accepted by a city buyer, assuming of course that his reputation for business integrity and financial soundness is satisfactory, they telegraph acceptance of his order, usually giving the number and initials of the car used to fill it, as well as the number and varieties of the baskets included. The buyer, with his order, has furnished shipping directions, according to which the car is billed out and turned over to the transportation company. The shipper then takes the bill of lading, received from the railroad, to his banker, and instructs him to draw a sight draft on the buyer. The banks in this section are usually willing to finance these dealers and advance them cash for 75 per cent of the face value of this draft, accepting the bill of lading as security. The bill of lading, with the sight draft attached, is then mailed to the correspondent bank through which the buyer deals, if possible in the city to which the cars are destined. The arrival of the sight draft attached to the bill of lading is usually approximately coincident with the arrival of the car, and the buyer is informed in each case. He then inspects the car, which is permitted in the standard form of contract and bill of lading. If he believes that the grade and quality are up to the standard agreed upon he accepts it. He does this by going to the city bank and "taking up" the sight draft. He pays its face value, receives the bill of lading, and thereupon accepts title to the shipment.

For this service the local banks in Michigan charge a fee of 25 cents per \$100 face value of the draft, and the balance is credited upon payment of the draft, less any costs charged by remitting banks and less also an interest charge of 6 per cent on the money advanced, after five days' grace expire. These are the standard terms to brokers. Cooperative associations are given financial accommodations on nearly the same basis, but must have a sufficient balance on hand to cover all transient drafts.

One of the most frequent causes for friction between shippers and receivers is the privilege of rejection at destination, incident to this type of sale. No one can deny the right of the receiver to refuse stock which does not come up to the quality agreed upon, but the complaint of shippers is that in a falling market even good stock is rejected as unsound. This, of course, is sharp practice and is condemned by the more honest members of the trade. In this connection mention should be made of the Food Products Inspection Service of the Bureau of Markets, which, in many of the larger markets, makes official inspection upon request of the shipper or receiver at a cost of \$4 per car or \$2.50 on small lots, and issues certificates as to the quality and condition of the stock which constitute prima facie evidence in the event of a dispute.

When a buyer decides to reject a car, he refuses to accept the sight draft and bill of lading and usually notifies the shipper to that effect, often telegraphing a new offer for the car. This the shipper may accept or decline, and in the latter case he can sell to other dealers in the same market or divert the car to another city. Any one of these courses necessitates new arrangements with both the receiving and remitting bank. Frequently, upon claim by the receiver, a shipper will grant a firm with which he has done business for some time a certain "allowance" or the discount of a few cents per basket on stock that arrives in bad condition, even though the receiver accepts the draft.

CARLOADS F. O. B. CASH TRACK.

In its simplest form the type of sale known as "f. o. b. cash track" consists in the purchase of a loaded car of grapes, ready for shipment, by a traveling representative of a city dealer, of a juice factory, or of a distributing agency, payment to be made before the car moves. This type of sale is practiced to an increasing extent in all sections. But cash track sales are sometimes made in New York and in Michigan upon telegraphic orders when the buyer agrees to accept the cars at shipping point and has made arrangements to telegraph the amounts due. Another financial arrangement is for

the buyer to deposit money at the shipper's bank, allowing draft to be made at the time of shipment, or even to have his own bank guarantee a credit up to a certain amount and have draft made directly upon the city bank. Thus sales made "shipping point acceptance, bank guarantee" are in reality a type of "cash track sales."

RELATION OF "CASH TRACK" AND "USUAL TERMS" SALES.

The primary difference between "cash track" and "usual terms" sales is the place in the transaction where the actual change of ownership occurs. Of the two methods, sales made on the basis of "carloads f. o. b. cash track" are to the benefit of the seller or shipper, and sales made on the basis of "carloads f. o. b. usual terms" are to



FIG. 3.—Grapes arriving at the terminal market.

the benefit of the buyer or receiver. In the former case the buyer assumes a risk as to the honesty and business integrity of the shipper, and in the latter case the shipper assumes a risk as to the honesty and financial ability of the receiver. Further, in "f. o. b. cash track" sales the buyer assumes all risks of deterioration in transit, delays, etc., and the shipper is relieved of these risks, while in the case of "f. o. b. usual terms" sales, at least in present-day commercial practices, the case is reversed, and the shipper takes the risk. In many cases these risks cause one of the parties heavy losses.

Thus we find shippers anxious to sell "cash track" even at a slightly lower price and buyers trying to make purchases on the basis of "usual terms." Which of these may succeed in this commercial competition depends on the organization of either class of factors and upon the conditions of supply and demand. In years

of crop shortage, when buyers are clamoring for shipments and hunting to find them, many sales are made on the basis of "cash track," while in years of normal supply the shippers have to seek buyers and are thereby forced to sell on "usual terms."

In the case of oversupplied markets, or when the average quality of the stock is poor, it is sometimes impossible to sell all of the grapes ready for shipment on an f. o. b. basis. Under these conditions the only alternative is to consign to dealers in the large terminal markets for sale on a commission basis, or to sell through city brokers.

SALES ON ACCOUNT.

Account sales are of two general types, "joint accounts" and "open accounts." Joint account sales are common in the Chautauqua-Erie belt and to some extent in the Central Lakes, and are infrequently seen in other important sections. Deals of this sort presuppose an agreement between a shipper, usually a local buyer, and a carlot receiver in a terminal market, whereby the two enter into a virtual partnership to buy, ship, and sell grapes, the final profits being divided between the two, usually on the basis of joint account.

Open account sales are common in the Chautauqua-Erie belt and are variable in type, their particular characteristic being that they are made between shippers and dealers who are mutually confident in each other's integrity and financial soundness, so that sales are made at what the shipper says is the market price and allowances are made for the arrival of stock in markets in poor condition, on the word of the buyer, and for a falling market. After the car arrives in market and is sold the buyer remits to the shipper, thus closing the account.

SECTIONS WHERE F. O. B. SALES ARE MADE.

While the great bulk of the commercial crop of the East is marketed by these methods, f. o. b. sales are seldom found outside of the few highly specialized grape districts, where each of the larger shippers is able to offer several cars a day. In Michigan, the Chautauqua-Erie belt, parts of the Central Lakes district of New York, the Hudson Valley of New York, and parts of the Missouri Valley district, factors, local dealers, or cooperative associations have so developed their business and established contacts in the cities to which they usually sell that they are enabled to make most of their sales on telegraphic orders, especially in seasons of short production. In outlying parts of these districts and in the less important sections of Delaware, the Southeast, New Jersey, the Ontario shore of New York, and parts of Missouri, few sales are made on an f. o. b. basis, as, except in a few instances, there are

not sufficient cars shipped from any one point to establish its reputation and to cause carlot buyers to investigate its possibilities. Most cars from these districts are rolled unsold, generally on consignment.

DESCRIPTION OF LEADING PRODUCING SECTIONS.

THE CHAUTAUQUA-ERIE BELT.

LOCATION AND EXTENT.

The Chautauqua-Erie belt is probably the most specialized grape-growing section in the United States outside of California. The industry reaches its highest development around the towns of North East, Pa., and Brocton, Portland, Westfield, and Ripley, N. Y. The commercial vineyards are found in a long narrow strip of land running from Eden, N. Y., to Girard, Pa., along the shore of Lake Erie, including parts of the counties of Erie, Pa., and Chautauqua, and Erie, N. Y., and to a much less extent parts of Cattaraugus County, N. Y.

Portland and Brocton, N. Y., are the leading shipping points of 2-quart baskets; Ripley, N. Y., and North East, Pa., of 4-quart baskets, and the 12-quart trade is the most important at Brocton, N. Y., and North East, Pa. Large grape-juice factories are established at North East, Pa., and at Westfield, Ripley, Brocton, Fredonia, and Silver Creek, N. Y.

Table 2 shows the carloadings at the various stations throughout the belt as reported to the Bureau of Markets by the originating railroads:

TABLE 2.—*Carloadings of grapes in the Chautauqua-Erie belt.*

	1916	1917	1918	1919		1916	1917	1918	1919
Erie Co., N. Y., Sept.-Dec.:					Chautauqua, Co., N. Y.,				
Angola.....	42	89	6	68	Aug.-Nov.—Continued.				
Buffalo.....	2	0	0	0	Silver Creek.....	132	114	8	211
Derby.....	3	6	0	13	Smiths Mills.....	44	17	4	33
Eden Center.....	47	86	12	112	State Line.....	133	33	40	0
Farnham.....	2	9	0	14	Van Buren.....	0	5	0	0
Lawtons.....	0	0	0	1	Vineyard.....	0	1	2	0
North Collins.....	66	85	6	50	Westfield.....	148	120	6	68
					West Perrysburg.....	0	0	0	75
Erie Co. total.....	162	275	24	258	Chautauqua Co. total	2,255	1,636	526	1,921
Cattaraugus Co., N. Y.,					Unknown, loaded in New				
Oct.-Nov.: Perrysburg.	97	77	11	23	York.....	0	318	161	0
Chautauqua Co., N. Y.,					Erie Co. Pa., Sept.-Nov.:				
Aug.-Nov.:					Erie.....	13	0	0	0
Brocton.....	423	325	95	296	Fairview.....	6	6	2	7
Dunkirk.....	28	26	0	10	Girard.....	9	0	0	23
Forestville.....	137	135	31	158	Harbour Creek.....	252	143	64	204
Forsythe.....	0	0	29	0	Moorheads.....	63	53	34	49
Fredonia.....	241	224	14	268	North East.....	666	620	223	727
Irving.....	90	11	0	39	Springfield.....	3	2	0	3
Laona.....	44	22	0	40	State Line.....	0	3	14	0
Mayville.....	17	36	0	24	Unknown.....	0	0	30	0
Minton.....	0	0	7	0	Erie Co. total.....	1,012	827	367	1,013
Portland.....	332	190	124	282	Total loadings in belt	3,526	3,133	1,089	3,218
Pratts.....	0	7	0	0					
Prospect.....	16	0	0	0					
Ripley.....	352	258	102	211					
Sheridan.....	118	112	64	209					

The topography of this section causes a strict demarcation of the area suitable for grape growing and localizes the vineyards to the territory between the lake and the long ridge which roughly parallels it. On the lake side of the ridge the soil is a rich clay loam underlaid by limestone and shale and alternating with gravelly loam, an ideal grape soil. The effect of a large body of water upon the temperature is to reduce frost damage to a minimum and the steady lake winds give the belt almost perfect immunity from fungus diseases. These two factors, together with the character of the soil, make this section an almost ideal place for grape production.

HISTORY.

The commercial grape industry in this region began in the eighties, when the first shipments in carload lots were made. The prices realized, in some cases between \$200 and \$250 per ton, were so satisfactory that farmers began to plant extensive vineyards, cooperative marketing associations were formed, and individuals entered the field as buyers and independent shippers. The growth of the industry was rapid and at one time the shipments of the belt were estimated at 8,000 cars a year. During the past three years, however, acreage and production have both declined because of a root-worm injury which left the vines in such a weakened condition that they were unable to withstand the recent severe winters.

Clean culture is generally practiced, and is often supplemented by cover crops of rye, barley, buckwheat, or red clover. Generally the vineyards are plowed in both fall and spring and usually either manure or a commercial fertilizer is applied.

ACREAGE AND VARIETIES.

The Concord is the chief grape of the belt, and it is roughly estimated that 95 per cent of the commercial acreage is of that variety. The Worden is next in importance and probably comprises 3 per cent of the crop. The Moore, Niagara, Delaware, and Agawam make up the remaining 2 per cent. The Moore and Worden are the first to mature, moving heavily in a normal season from about the second week in September until the first week in October. Concord starts the last week in September or the first week in October and are usually cleaned up by November 1. The Niagara, the Delaware, and the Agawam, known locally as "varieties," are generally shipped early in October.

The commercial acreage of the belt is variously and unofficially estimated as from 33,000 to 35,000 acres, which is a material reduction from the number devoted to grapes three or four years ago. No official statistics as to production are available, but it is the consensus

of opinion of those in close touch with the situation that for the decade preceding 1916 the average yield per acre approximated 2 tons. The yield was materially reduced in 1917 by a very severe early freeze and in 1918 by a combination of rootworm injury and the winterkilling of the previous season. Very little replanting is being done.

MARKETING METHODS.

While practically all known methods of marketing are used in the belt, two general types of sale greatly predominate—sales to local buyers and sales to grape-juice factories. These factors are for the most part reliable, up-to-date business men, who have the interests of the industry at heart. The juice factories of the belt have more prominence than in any other section and furnish an easy and profitable outlet through which the grower may dispose of his crop. The importance of this phase of the industry is constantly increasing and will undoubtedly absorb the small quantity of grapes which have hitherto been used locally for wine manufacture. In normal years sales are made on an f. o. b. basis, which is facilitated by the high development of the industry in this section.

COOPERATION.

At present there are four growers' cooperative associations in existence in the belt, only one of which is of more than local importance. This association has been the largest handler of grapes in this section and largely through its efforts the high reputation enjoyed by this section and the wide distribution of its products has been developed. The organization devotes special attention to the New England trade and makes many sales in the smaller cities of Massachusetts and Connecticut. Because this association allows many of its members to sell direct to juice factories, its shipments have not been so large in recent years as formerly.

QUALITY OF PACK.

Careful trimming and packing and well-developed methods of handling the crop built up a high reputation for the grapes shipped from this section. The grape berry moth is troublesome in certain localities, but as fungus injury is generally very light, most of the grapes are picked into the shipping baskets directly from the vine. The pickers in this section are often paid by the basket. In this case it is to their advantage to place the bunches in the packages as loosely as possible. When the natural shrink is added, and the bunches are shaken down by the motion of the wagon and the freight car, these loosely packed baskets often reach the market with an inch margin

between the cover and the top bunch. Such short weight reacts upon the reputation enjoyed by this section and every one interested in the industry should strive to put a stop to this practice. The greatest responsibility rests upon the grower, who should take pains to secure a good, tight, full pack, remembering that the future of this section is dependent upon its recovery of the table-stock trade, and that every dissatisfied consumer reduces the terminal demand and the price.

MARKET OUTLETS AND DISTRIBUTION.

It is to be regretted that the data for the destinations of 1918 shipments only are available, as in that year production was far below normal and the field of distribution was materially reduced (see Appendix). However, it is known that shipments from this section have gone as far west as Denver, Colo., as far east as Portland, Me., and as far south as Atlanta, Ga. A very large number of the 1918 destinations show merely the interstation shipments, as from Ripley to Westfield, or from Brocton to Fredonia, of grapes intended for juice factories. It should be remembered that not all the carlot shipments represent table stock, as a very large percentage of the stock shipped in 12-quart baskets was used in the home manufacture of wine. This was especially true in the smaller cities of Pennsylvania and Ohio, where the proportions of the foreign-born population is large. Some of these cities are so small that a full carload of table stock could not have been consumed.

Although in 1918 the grapes from the belt went to 109 different cities and towns in two States, it can not be said that the shipments of this section show a generally wide distribution, as in that year nearly half went to four cities—Pittsburgh, Westfield, Boston, and Philadelphia. Much of the remainder of the crop went to parts of Pennsylvania, Ohio, and New York, adjacent to the belt. The Michigan competition prevents a greater expansion of outlets toward the West, and few cars are rolled in that direction until after the Michigan crop has been consumed, which in 1918 occurred earlier than usual. On the other hand, a fairly large business has been built up in New England, but the short crop in 1918 prevented the shipment of many cars to that section.

THE CENTRAL LAKES DISTRICT OF NEW YORK.

LOCATION AND EXTENT.

The Central Lakes district of New York is one of the most interesting and important grape-growing sections of the country. The deep, long lakes of Keuka, Canandaigua, Seneca, and Cayuga make

the climatic conditions most favorable for grape growing, and the steep banks and high hills surrounding Keuka Lake, together with the thickly planted vineyards at its side, have given it the name of "the Rhine of America."

The commercial vineyards in this district may be divided into three main sections, those contiguous to three of the lakes mentioned above—the Keuka Lake section, comprising parts of the counties of Yates and Steuben; the Canandaigua section, comprising particularly the Naples Valley and Canandaigua section in Ontario County; and the Seneca Lake section, parts of Seneca, Schuyler, and Yates Counties, and, to a very limited extent, Ontario County.

Table 3 shows the loadings at the various stations throughout this district, as reported by mail to the Bureau of Markets by the various originating railroads:

TABLE 3.—*Carloadings of grapes in the Central Lakes district of New York.*

	1916	1917	1918	1919		1916	1917	1918	1919
Ontario Co., Sept.-Oct.*					Steuben Co., Sept.-Nov.:				
Canandaigua.....	25	17	25	11	Hammondsport.....	199	99	108	191
Geneva.....	0	11	0	0	Prattsburg.....	0	0	0	4
Naples.....	124	89	77	160	Rheims.....	0	0	0	6
Orleans.....	21	0	0	0	Steuben Co. total....	199	99	108	201
Ontario Co. total....	170	117	102	171	Yates Co., Sept.-Nov.:				
Schuyler Co., Sept.-Nov.:					Benton.....	0	1	0	0
Hector.....	61	92	40	101	Bluff Point.....	127	125	55	132
Valois.....	30	28	19	46	Branchport.....	70	76	74	126
Schuyler Co. total....	91	120	59	147	Dresden.....	20	11	2	18
Seneca Co., Sept.-Nov.:					Dundee.....	1	3	4	7
Burdett.....	0	0	15	29	Glenora.....	1	1	0	0
Caywood.....	14	40	19	34	Himrod.....	32	45	18	32
Kendaia.....	62	41	9	50	Middlesex.....	137	141	63	144
Romulus.....	20	7	0	9	Milo.....	1	1	0	1
Seneca Falls.....	4	6	2	4	Penn Yan.....	508	298	149	260
Yale.....	1	0	0	0	Rock Stream.....	2	0	0	1
Seneca Co. total....	101	94	45	126	Starkey.....	45	28	15	41
					Yates Co. total.....	944	730	380	762
					Total loadings in district.....	1,505	1,160	694	1,407

HISTORY.

The earliest plantings recorded in the Central Lakes district were in Steuben County in 1830.⁴ The industry spread slowly around the other lakes, and in 1854 the first commercial shipment was made to New York City. Shortly after 1860, the Concord and the Delaware were introduced into the district, and in the eighties the Niagara became very popular, particularly in Seneca County. Had all the vines set in this county come into bearing, they would have flooded the markets, for distant shipments were not then practicable,

⁴ See Hedrick, U. P. The Grapes of New York. Report Agricultural Experiment Station for the Year 1907, II, pp. 83, 84.

as they are to-day. But this speculative enterprise was ill considered, many vines were planted in heavy clay soils, and few survived to come into bearing, as this variety is especially tender. Generally grapes do not do well in this district at an altitude beyond 200 feet above the lake level.

The particular development around Keuka Lake, where Catawbas are grown to greater perfection than anywhere else in the North, and in the Naples Valley, was toward wine production. The wine industry was begun in this section in the sixties, and by 1915 there were over 25 factories engaged in this process, Keuka Lake was the center of the American champagne industry, and important wine factories were in operation in Naples.

ACREAGE AND VARIETIES.

As in the other leading grape-producing sections, the acreage is on the decrease and the reduction has been particularly marked in Seneca County. The commercial acreage of the district is variously and unofficially estimated at from 12,000 to 15,000 acres. No official statistics as to the average production are available, but it is the consensus among those in close touch with the industry that the average yield per acre for the whole district was formerly about a ton, the low figure being due to the many uncared-for vineyards and the numerous varieties of low productivity.

The Central Lake district is notable for the lack of standardization upon a leading variety, nearly all the well-known varieties being grown in commercial quantities. No official data are available as to the relative acreage of the different varieties, but it is roughly estimated by leading factors that the Concord comprises 60 per cent of the acreage, the Catawba 20 per cent, Delaware 8 per cent, Niagara 7 per cent, and others, such as the Elvira, Worden, Moore, Ives, Diamond, Agawam, and the Brighton the remaining 5 per cent.

There is probably no commercial district where insect pests cause so little damage as around the Central Lakes of New York, but fungus diseases are troublesome; black rot, downy mildew, powdery mildew, anthracnose, and chlorosis often attack the fruit and vines. These fungus diseases necessitate repeated sprayings, and in recent years they have seemed to be under better control. On account of the frequent and extensive damage to the bunches, many of the best vineyardists use packing houses, but much stock, especially in the outlying sections, is picked directly into shipping baskets. A fairly good pack is usually shipped, particularly from the Penn Yan section, where there is one factor whose shipments command a considerable premium.

MARKETING METHODS.

Practically all known methods of sale are practiced in this region, but the principal outlet for the grower is through local buyers or car-lot assemblers. The contract system of sales is much in vogue. Growers often sell their crop to a local buyer before it matures, agreeing to pick and deliver at the buyer's packing house for a certain stipulated price. As the growers are often ignorant of the marketing conditions while the buyer is well informed concerning them, this system frequently works to the grower's disadvantage. For instance, during 1918 growers in the Chautauqua-Erie belt were selling their Concords at \$100 to \$110 per ton, while some growers in the Keuka Lake section were hauling similar stock at the previously contracted price of \$60 and in some cases as low as \$40 per ton. Other growers in this section, who were selling to the same buyer at the market price, were receiving \$90 to \$95. This last price is not out of line, for Central Lakes stock, except in the case of certain well-known brands, generally sells slightly below Chautauqua and Hudson River stock.

A large amount of stock, in the aggregate, is bought on contract by outside buyers who visit this district and purchase crops at a certain definite price, which depends upon the quality of each vineyard and upon the growers's knowledge of price conditions. It might be said in passing that as a large percentage of growers is extremely ignorant of marketing conditions and practices, good stock may often be purchased in Seneca, Ontario, Schuyler, and Yates Counties at low prices; therefore many of the growers in these sections fail to realize the full market price for their product.

In the Keuka section and in the Naples Valley large amounts of this stock were formerly used for the manufacture of wine, and the closing of this outlet will undoubtedly work a severe hardship in these sections; however, some of these factories expect to engage in the manufacture of grape juice.

A much larger percentage of table stock is shipped from this district than from the Chautauqua-Erie belt, 2-quart baskets being used almost exclusively. Eight-basket crates are sometimes employed for shipping fancy table stock, such as Delawares.

Consignment by growers, in less than carload lots and also in carlots, is frequently practiced, particularly from the district around Seneca Lake. As this consignment is generally done on a haphazard basis, growers shipping to certain markets merely because they did so the year before, it is not surprising that there is frequent dissatisfaction regarding the returns.

Prohibition legislation caused more disruption in the Central Lakes district of New York than in any other of the larger grape districts outside of Ohio, and this fact, together with the rather unorganized condition of the local trade, created more interest in marketing methods and caused the organization of several cooperative associations.

MARKET OUTLETS AND DISTRIBUTION.

The shipments from the Central Lakes district secure a wider distribution than those from any other section in New York and are the principal source of late supplies for the eastern and southeastern cities of the United States. Concords in this section ripen from 10 days to 2 weeks earlier than those of the Chautauqua-Erie belt, and during that time there is no competition between these two districts. When the belt begins to ship heavily on the West and the Hudson River Valley is shipping on the East, shippers in the Central Lakes district are hard pressed to find an outlet for their product. It is then that the shipments find their way into the more southern markets. Later, when Michigan is out of the market, some stock is rolled to the Middle West. It is noticeable that in 1918 both the Chautauqua-Erie belt and the Central Lakes district shipped heavily to the smaller cities in Pennsylvania, these shipments being largely of stock packed in 12-quart baskets for the home manufacture of wine. Largely on account of the location and directions of the railroads in these two sections, the shipments from the belt go to western Pennsylvania and from the Central Lakes to the eastern part of the State. Also, all New York shipping sections roll stock to New England. (See Appendix.)

THE HUDSON VALLEY OF NEW YORK.

HISTORY AND DESCRIPTION.

The production of table grapes in America first reached commercial importance in the Hudson Valley district.⁵ Before 1830 a vineyard of Catawbas and Isabellas was shipping to neighboring markets. This district is notable for the extensive experimental work that was done in the early days of the industry, in the production and dissemination of new varieties. This was an undoubted

⁵ See Hedrick, U. P. The Grapes of New York. Report of the New York Agricultural Experiment Station for the Year 1907, II, p. 89.

boon to the industry, but its effect upon the district was questionable, for it resulted in the planting of many acres to commercially worthless varieties. There was great expansion previous to 1890, but between that date and 1900, when competition from other districts became stronger and fungus diseases began to affect the production seriously, there was a sharp decrease in the acreage of this district.

The soil of the Hudson Valley district is variable, most vineyards being found on coarse gravelly loams, in which shale or slate predominate. Most of the grapes are grown on the hills near the river, which has a stabilizing effect upon the temperature. Without this large body of water, grape growing would be impossible in this section. As it is, the winters are often destructive.

The district comprises the counties of Columbia, Dutchess, Ulster, and Orange. Germantown, Roseton, Highland, Marlboro, Milton, and Ulster Park are the most important shipping points.

Table 4 shows the loadings at the various stations throughout the territory, as reported to the Bureau of Markets by the originating railroads and boat lines:

TABLE 4.—*Carloadings of grapes in the Hudson Valley of New York.*

	1916	1917	1918	1919		1916	1917	1918	1919
Columbia Co., Aug.-Sept.:					Ulster Co., Aug.-Oct.:				
Claverack.....	0	0	0	6	Clintondale.....	2	2	0	3
Elizaville.....	0	0	0	17	Esopus.....	9	7	10	0
Germantown.....	19	59	124	126	Highland.....	29	70	23	14
Hudson.....	0	0	0	5	Marlboro.....	98	91	114	102
Columbia Co. total..	19	59	124	154	Milton.....	19	15	32	0
Dutchess Co., Sept.-Oct.:					St. Elmo.....	1	0	0	1
Barrytown.....	2	3	0	7	Ulster Park.....	49	46	16	32
Cokertown.....	4	2	0	0	West Park.....	9	6	13	0
Red Hook.....	0	0	0	6	Ulster Co. total....	216	237	298	152
Tivoli.....	8	14	5	25	Unknown.....	0	171	187	0
Dutchess Co. total..	14	19	5	38	Total loadings in Hudson Valley...	276	566	573	344
Orange Co., Aug.-Oct.:									
Cedarchiff.....	8	25	9	0					
Newburgh.....	2	0	8	0					
Roseton.....	17	55	32	0					
Orange Co. total....	27	80	49	0					

VARIETIES.

There is no commercial necessity for such a great number of varieties as are produced in this district, but because of the proximity of so many markets where small quantities of fancy stock may be sold to advantage there are many varieties left from earlier times. No official statistics are available as to the relative acreage of the different varieties, but it is roughly estimated by leading factors that the

Concord comprises 50 per cent of the acreage, the Delaware 15 per cent, Niagara 15 per cent, Worden 5 per cent, Moore 5 per cent, and others, such as the Bacchus, Pocklington, Campbell, Hartford, and the Virgennes, the remaining 10 per cent.

METHODS OF SALE.

All known methods of sale are practiced, but shipment on consignment in less than carload lots by water freight is one of the most common. As the commercial vineyards are all adjacent to the river, which is navigable as far as Albany and Troy, many growers take advantage of the low freight rate and quick delivery in shipping to New York. Fruit loaded on the boat late in the evening will reach the city in time for business the next morning. The great drawback of this method is that it confines shipments to New York, Brooklyn, Albany, and Troy. The wider distribution of the products of this district is effected by the local dealers and associations.

At several points local dealers control the situation, buying the offerings of the growers and selling them in carloads "f. o. b. usual terms" or "f. o. b. cash track," preferably the latter, to their connections in outside cities.

A grape-juice factory is established at Highland, which annually consumes a large amount of stock and offers an easy outlet for the products of the vineyards.

In recent years the growers of this district have formed a cooperative association through which their products are sold. This association has been successful in disposing of its offerings to advantage, and is now one of the most important factors in this district.

QUALITY OF PACK.

Damage by insect pests is practically negligible, but fungus diseases, particularly black rot, are often very harmful. This sometimes results in a poor pack, but on the whole the quality of the shipments from this district is good. Two-quart and 4-quart baskets are generally used, most of which are packed in the vineyard. On account of the numerous varieties commonly grown, a practice has developed of packing two or three varieties in one basket, which finds some favor with the fancy trade.

MARKET OUTLETS AND DISTRIBUTION.

New York is by far the heaviest receiver of Hudson Valley shipments, with Boston next in importance. Most of the remaining grapes go to the smaller cities in eastern New York State and in New England and an occasional car is shipped into Pennsylvania and

New Jersey, but because of the heavy competitive shipments from the Central Lakes and the Chautauqua-Erie belt, the prevailing shipping tendency is toward the East.

THE ONTARIO SHORE OF NEW YORK.

LOCATION AND EXTENT.

The Ontario shore of New York, sometimes called the Niagara district, both from the principal county and the principal variety of this section, is relatively unimportant, when compared with the Chautauqua-Erie belt and the Central Lakes district which lie near it. The acreage of the whole section has lately been on the decline, largely on account of severe winter injury.

The general topographical features of this section are similar to those of the Chautauqua-Erie belt. Although commercial shipments are made from seven different counties, the industry is not of great importance outside of Niagara County, where Lockport, Model City, and Sanborn are the most important shipping points.

Table 5 shows the loadings at the various stations throughout this section, as reported to the Bureau of Markets by the various originating railroads.

TABLE 5.—*Carloadings of grapes in the Ontario shore district of New York.*

	1916	1917	1918	1919		1916	1917	1918	1919
Genesee Co., Oct.:					Orleans Co., Sept.:				
Pavilion.....	0	1	0	0	Fancher.....	3	0	0	0
Monroe Co., Oct.:					Holley.....	0	1	0	4
Brookport.....	3	1	0	0	Medina.....	0	2	2	0
Union Hill.....	2	0	0	0	Millers.....	0	0	1	4
Monroe Co. total....	5	1	0	0	Orleans Co. total....	3	3	3	8
Niagara Co., Sept.-Oct.:					Oswego Co., Sept.:				
Burt.....	0	1	0	0	Lacona.....	32	0	0	0
Cambria.....	3	7	0	3	Wayne Co., Oct.:				
Elberta.....	6	7	3	15	Newark.....	0	0	2	0
Gasport.....	9	5	2	10	Ontario.....	6	5	2	17
Lewiston.....	0	3	0	12	Sodus.....	8	0	0	7
Lockport.....	67	34	25	64	Wayne Co. total....	14	5	4	24
Model City.....	28	20	20	54	Total loading for				
Mortimer.....	0	3	0	0	district.....	194	108	66	259
Ransomville.....	6	3	1	12					
Sanborn.....	12	9	5	43					
Wilson.....	9	6	3	14					
Niagara Co. total....	140	98	59	227					

The yield in this section is low because the Niagara, the chief variety grown, is a light bearer. It is roughly estimated that about 80 per cent of the commercial acreage is planted to the Niagara, 10 per cent to the Concord, and that the remainder is composed of the Worden, Moore, Delaware, and other less important varieties.

There are few large plantations. In fact, this section is interesting from a commercial viewpoint merely as a shipper of Niagaras, for nowhere does this variety reach such a high quality as near Lake Ontario, and particularly in Niagara County.

METHODS OF SALE.

A large percentage of the sales by growers in the counties of Genesee, Monroe, Orleans, and Wayne are made direct to retailers or to city markets in the near-by cities and towns. An important outlet is the shipment in less-than-carload lots on consignment to cities within the State, as to Buffalo, Rochester, Syracuse, and Rome. Some of the sales in these counties are made through local dealers who specialize in other fruits and handle grapes only as a side line.

While there is some carlot shipping by growers, the greater part of the commercial distribution is effected by an association formed by growers for the marketing of their product. This association also handles some grapes in the Central Lakes district. The principal outlet for the carlot shipments from this district is in the large cities of the East—New York, Boston, and Philadelphia, and also in Pittsburgh.

Insect pests are not particularly troublesome in this section, but fungus diseases, especially black rot, to which the Niagara is very susceptible, does considerable damage and necessitates careful trimming in years of infection.

MICHIGAN.

LOCATION.

While the quantity production of Michigan grapes does not equal that of New York State, nevertheless, as the shipments of table stock are heavier, the distribution more extensive, and the industry localized in a single section, southwestern Michigan may be regarded as the leading grape section of the East.

While carlot shipments have been made from 10 Michigan counties during the last three years, the industry is relatively unimportant outside the counties of Van Buren and Berrien, and reaches its highest development around the towns of Lawton, Paw Paw, and Mattawan in the former county and Benton Harbor and St. Joseph in the latter.

Table 6 shows the loading at the various stations throughout the State as reported to the Bureau of Markets by the various originating railroads.

TABLE 6.—*Carloadings of grapes in Michigan.*

	1916	1917	1918	1919		1916	1917	1918	1919
Allegan Co., Sept.:					Kent Co., Sept.:				
Fennville.....	6	0	0	22	Belmont.....	0	1	0	0
Berrien Co., Sept.-Oct.:					Englishville.....	0	1	0	0
Baroda.....	69	136	9	0	Grand Rapids.....	2	12	0	25
Benton Harbor.....	257	740	603	1,255	Rockford.....	0	2	0	3
Berrien Springs.....	5	12	0	21	Sparta.....	0	0	0	2
Bridgman.....	52	104	17	0	Kent Co. total.....	2	16	0	30
Colonia.....	22	81	36	157	Mason Co., Sept.-Oct.:				
Derby.....	168	237	1	288	Ludington.....	3	0	0	0
Fairland.....	0	12	7	0	Muskegon Co.: Oct.:				
Gallen.....	4	1	0	1	Slocum.....	3	0	0	0
Glendora.....	0	1	0	0	Ottawa Co., Sept.-Oct.:				
Harbert.....	0	2	1	0	Grand Haven.....	40	28	0	1
Hinchman.....	0	27	0	0	Spring Lake.....	0	0	0	3
Napier.....	0	59	0	0	Ottawa Co. total....	40	28	0	4
Niles.....	3	6	0	21	Van Buren Co., Sept.-Oct.:				
Riverside.....	2	18	0	15	Bangor.....	1	4	0	1
Royalton.....	0	1	0	0	Breedsville.....	1	0	0	0
St. Joseph.....	255	512	210	498	Decatur.....	18	28	4	25
Sawyer.....	29	39	33	105	Gobles.....	0	4	0	4
Scotdale.....	0	180	0	0	Hartford.....	15	16	7	2
Sodus.....	38	55	51	175	Kendall.....	1	2	0	3
Stemms.....	0	4	0	0	Lake Cora.....	0	0	4	0
Stevensville.....	48	95	81	27	Lawrence.....	3	12	11	18
Vineland.....	0	0	6	0	Lawton.....	336	427	77	328
Union Pier.....	0	1	1	0	Mattawan.....	155	261	44	158
Watervliet.....	2	3	1	2	Paw Paw.....	272	509	254	473
Berrien Co. total....	954	2,326	1,057	2,565	South Haven.....	0	8	0	17
Cass Co., Sept.-Oct.:					Van Buren Co. total	802	1,271	401	1,029
Dowagiac.....	5	16	5	17	Unknown.....	0	0	169	88
Edwardsburg.....	1	1	0	0	Michigan State total	1,849	3,667	1,637	3,795
Marcellus.....	26	0	5	34					
Cass Co. total.....	32	17	10	51					
Grand Traverse Co., Oct.:									
Traverse City.....	1	0	0	0					
Kalamazoo Co., Oct.:									
Rix.....	0	2	0	0					
Williams.....	6	7	0	6					
Kalamazoo Co. total.	6	9	0	6					

HISTORY.

Grape growing is a younger industry in Michigan than in the States of New York, Pennsylvania, or Ohio. According to excellent local authority, the first commercial vineyards were planted in Lawton in the early seventies. The good returns received by this pioneer planter caused others to go into the production of grapes. The acreage was at first restricted to the district around Lawton, Paw Paw, and Mattawan, but soon spread toward the south and west, including the Benton Harbor-St. Joseph district. As in the early rapid expansion of almost all commercial sections, the acreage spread toward unfavorable localities in Van Buren and Berrien Counties, including the heavy land of the south, and the lowlands. Grapes were found to be unprofitable in these places and only a few scattered and relatively unproductive plantations now remain. Thus it has been demonstrated that only on the lighter soils where good air drainage exists does grape growing prove profitable.

Severe attacks of black rot seemed to threaten the industry between 1905 and 1910 and caused the abandonment of many acres, but it was soon found that careful spraying would reduce the effects of this disease to a minimum.

The methods of commercial disposition of the crop have gone through the usual evolution. In the early days near-by markets like Chicago, Lansing, and Detroit received the bulk of the shipments, which were usually forwarded on consignment; but now the extent of distribution of Michigan's shipments and the strength of its f. o. b. market is unequaled in the grape industry of the East.

ACREAGE AND VARIETIES.

No accurate or official data are available as to the present production and acreage in Michigan, but the indications are that replantings have almost, if not quite, equaled the acreage abandoned. The decrease in shipments in 1918 was due to a very light yield caused by unfavorable weather conditions, and can not be traced to any decrease in the number of vines. Substantiating this statement, local information puts the average yield per acre at $1\frac{1}{2}$ to $1\frac{3}{4}$ tons and the yield for 1918 at two-thirds to seven-eighths of a ton.

The Concord is here preeminently the leading variety, with the Champion and the Moore next in importance. The Worden, Delaware, Niagara, and other varieties are grown, but their relative importance is slight. In the absence of official statistics, well-informed local opinion places the acreage of the various varieties as follows: Concord 85 per cent, Champion 7 per cent, Moore $6\frac{1}{2}$ per cent, and others $1\frac{1}{2}$ per cent. It is interesting to note that the Champion is being replaced by the Concord to a marked extent, as progressive growers think that the Champion, which is a grape of low quality, reaching the market before any other variety, has a deleterious effect on the general consumptive demand.

The Champion usually begins to move heavily during the second week in September and cleans up in 10 days to 2 weeks. The Moore Early generally begins from 3 days to a week later, their normal season continuing about 10 days. Most of the other varieties are shipped late in September. The Concord, which comprises the main Michigan crop, begins to move in heavy volume between the middle of September and the 1st of October, and usually continues for a period of about a month.

MARKETING METHODS.

The highest development of grape-marketing machinery is found in Michigan, and practically the whole crop is sold on an f. o. b. basis.

COOPERATION.

Cooperative organization has reached a high state of development in this State, particularly in the grape-growing sections, and practically all the shipments from Van Buren County and many from Berrien are made through these associations.

The tendency in the growth of the cooperative movement in Michigan seems to have been first toward localization and is now toward federation. The individual associations are small and seldom control loadings at more than a few stations, thus differing markedly from some of the most successful associations in other States. The movement toward federation of these various small associations is a promising solution of the rather unfortunate spirit of competition that often arises between the individual organizations.

These small associations are usually stock companies that own their own offices and market the grapes of their members, usually on the basis of a daily pool of varieties. Most of them handle other fruits as well, and also buy baskets, twine, spray material, and even posts, hay, and feed for their members. Few of the individual associations actually sell the grapes, but confine their activities to inspection and loading, keeping accurate records of the amounts of each variety delivered daily. The usual practice is to give each member 75 or 80 per cent of the estimated market value of each day's haulings and to prorate the surplus among the members when the books are balanced at the close of the season, the returns to stockholders depending on the particular arrangements of each association.

The shipments by these small associations are sold in the main by one or the other two large agencies—the one a distributing company of national scope, which charges a brokerage fee for its services, and the other a cooperative federation of the associations themselves.

GRAPE-JUICE FACTORIES.

All of the grape-juice factories of this region are located in Van Buren County. Lawton is the center of the industry, with a smaller development at Paw Paw and Mattawan. Most of the factories buy on a standard contract which guarantees the grower the daily market price on bulk stock, with a fixed minimum. As Michigan bulk shipments are light, a daily market price on this class of stock often fails of establishment, and it is left to the juice factories to state the price for each day. These factories sometimes buy in Berrien County for shipment, but most of the stock is secured by local haulings, which fact explains the very light shipments from Lawton in 1918.

THE STREET MARKETS.

The street markets in Benton Harbor and St. Joseph constitute an interesting development in the Berrien County section. These cities are surrounded by many extensive vineyards, though in the main the individual holdings are considerably smaller than in Van Buren County. The size of these holdings, and consequently the large number of growers, probably had an important bearing on the establishment of the type of market at these points, for while in Van Buren County cooperation developed among the growers, in the street markets of Benton and St. Joseph there is found an extreme development of competition among the buyers.

The street sales form what is practically an auction market, for the farmers sell their output daily by driving to certain crowded street corners in these cities, where they receive bids for their loads. Informal regulations are agreed to; the farmers' wagons form in lines at certain corners, beyond which no buyers pass. The buyers congregate around each wagon as the line moves up and each makes a bid, the highest of which is usually accepted. However, if the grower feels that he can secure larger returns by consigning his shipment by freight or express to some city market he refuses even the highest bid and drives on to the railroad station. With this end in view, many growers address each basket with a rubber stamp to facilitate shipment.

There is much controversy as to whether the returns from cooperative associations or street sales net the greatest profit to the grower, but the observations made by this bureau in 1918 show that only for a short period, when the Champion crop was cleaning up, did the street prices to growers exceed those paid by associations. This was due in part to the better average quality of the associations' stock produced under close inspection and in part by the very nature of the business of the two types of factors, for the local buyers, who dealt on the street market, had to sell their grapes on a basis fairly comparable with the f. o. b. prices received by the associations themselves.

Usually the street prices reflect very closely the daily quotations from the tributary terminal markets, but in a few cases temporary abnormally high or low prices result from the vagaries of supply and demand. For example, on some evenings several buyers have carloads or boatloads nearly completed and bid up stock to high prices in order to secure quantity transportation rates, conversely relatively low levels often prevail because available carriers are completely loaded.

QUALITY OF PACK.

The conditions of production on the whole are very good in this State, as careful cultivation, fertilization, pruning, and spraying are practiced. Michigan is singularly free from insect pests, but the black rot is troublesome and at times causes serious loss. Almost without exception, table stock is shipped in the 4-quart basket, which has become the standard Michigan container. The baskets are packed in the field, directly from the vines, and a good pack is generally turned out. There is much local discussion as to the relative quality of the pack of cooperative associations, of independent growers, and of the stock sold on the street markets. Usually the pack of the associations is slightly superior. The relative quality of Michigan and New York shipments is another much-discussed point, for shippers from New York claim to put up a much more fancy product. The fact that Pittsburgh and Chicago, the two most important markets where the shipments come into direct competition, consistently pay a slight premium for the New York stock would seem to corroborate this, but it is doubtful whether the difference is not more fancied than real, for while the Michigan stock has been improving in recent years, it is believed by impartial observers that the quality of the New York pack in general has been deteriorating.

The Climax baskets used in Michigan are often of coarse stock and do not present such an attractive appearance as the New York baskets. Many Michigan shippers refuse to label the baskets, although this costs only about one-fourth of a cent and usually secures a premium of 1 to 3 cents per basket. These shippers have not conducted such an active campaign of advertisement of the quality of their stock as have the New York factors. Another cause for this market preference is that many Champions, a variety of very low quality, have been shipped from Michigan. Growers have come to realize that this variety has a depressing effect on the general demand for Michigan stock and are rapidly replacing the Champion with the Concord. If those interested in the Michigan industry would pay more attention to these points, there seems no reason why the trade should not come to recognize fully the high quality of the stock from this State.

MARKET OUTLETS AND DISTRIBUTION.

While New York has been diverting its grapes from table stock to wine and juice manufacture during the past few years, Michigan has been developing new markets and a system of extensive and intensive distribution, unequaled in the grape industry farther east. The

shipments from this State are no longer confined to neighboring territories. Even in the short crop year of 1918 cars were rolled east to Massachusetts and New Jersey, south to Florida and Texas, and west to Idaho and Wyoming. In that year carlot shipments were made to 31 different States and to 169 different cities.

The largest market for this section is Chicago, to which much stock is carried by water freight, Berrien County occupying the same relative position to this city that the Hudson Valley district does to New York. Heavy shipments are also made by water to Milwaukee and other lakeside points.

The general tendency is to ship toward the West and South; States east of Michigan receive but a small proportion of the total shipments. Besides the adjacent States of Illinois, Wisconsin, Indiana, and Ohio, the Missouri Valley States of Iowa, Missouri, Nebraska, and Kansas are heavy receivers.

OHIO.

LOCATION AND EXTENT.

The number of carlot shipments that have moved out of Ohio during the past three years, as shown in Table 1, give no adequate idea of the importance of the Lake counties of this State. Ohio follows New York and Michigan in importance, and while its production is much more scattered than that of Pennsylvania, in total annual tonnage it probably excels that State. The grape sections of Ohio are, in effect, a western continuation of the vineyard section of the Chautauqua-Erie belt, and every lakeside county is a fairly heavy producer.

The proportion of the stock pressed to the stock shipped out is higher in Ohio than in any other important eastern State, and as much more of this pressed stock was used for wine than for grape juice, it is evident that in Ohio the industry is now undergoing a radical readjustment.

Lake County, of which the principal shipping point is Unionville, Cuyahoga County near Dover, Erie County near Sandusky, and Kelleys Island are the three most intensive producing sections in the State. The Sandusky section, which includes Kelleys Island, has rivaled Hammondsport, N. Y., as a center of the American champagne industry and has used for this purpose a large proportion of the Catawbas produced locally.

Table 7 shows the carloading at the various points in Ohio, as reported to the Bureau of Markets by the originating railroads.

TABLE 7.—*Carloadings of grapes in Ohio.*

	1916	1917	1918	1919		1916	1917	1918	1919
Ashtabula Co., Sept.-Oct.:					Lake Co., Sept.-Nov.:				
Amboy.....	0	1	0	0	Madison.....	19	48	2	10
Ashtabula.....	1	0	0	0	Perry.....	51	48	11	32
Conneaut.....	3	0	0	1	Unionville.....	104	39	12	31
Geneva.....	9	12	6	3	Lake Co. total.....	174	105	25	73
Saybrook.....	3	0	0	0	Lorain Co., Sept.-Oct.:				
Ashtabula Co. total.....	16	13	6	4	Avon.....	21	16	13	7
Cuyahoga Co., Sept.-Nov.:					Ottawa Co., Sept.-Oct.:				
Dover.....	31	43	0	0	Danbury.....	1	2	0	0
Erie Co., Oct.:					Gypsum.....	0	0	1	0
Berlin Heights.....	2	4	2	5	Port Clinton.....	0	2	4	6
Ceylon.....	2	1	0	1	Put in Bay.....	1	6	0	0
Vermillion.....	9	23	3	12	Ottawa Co. total.....	2	10	5	6
Erie Co. total.....	13	28	5	18	Ohio State total.....	258	215	54	108
Geauga Co., Oct.:									
Chardon.....	1	0	0	0					

ACREAGE AND VARIETIES.

Taking the State as a whole, the Concord occupies the bulk of the acreage, but in all the lake counties, particularly Erie and Sandusky, the Catawba is relatively very important. The proportion of the Delaware and the Niagara, particularly in Cuyahoga and Lorain Counties, is also larger than in most other commercial sections.

No figures are available as to the acreage or average yield, but two facts are apparent: (1) That the acreage has been materially reduced by the combined effects of the recent severe winters and the ravages of the rootworm, which is particularly destructive in many parts of the State; and (2) that the average yield is much lower than in other commercial sections, due principally to the large, partially abandoned, acreage and also in part to the large proportion of varieties, such as the Catawba, the Delaware, and the Niagara, which are relatively light yielders.

At one time grape growing assumed considerable importance in the southern part of the State along the Ohio River, but these vineyards have long ceased to figure in commercial shipments.

METHODS OF SALE AND MARKET OUTLETS.

As might be expected in a State where such a large proportion of the stock has been consumed by wine and juice factories, the contract type of sale predominates. As a general rule, these factories have not bought their required tonnage at the market price, as in New York and Michigan, but at a price agreed to early in the season, before the grapes matured. These establishments entered the market at picking time only when a short crop year cut down their pre-

viously contracted tonnage below their requirements. No small degree of dissatisfaction is felt among many of the growers over these methods.

The table-stock industry is being developed at present. Several movements are under way toward the formation of cooperative associations among the growers. These are deterred somewhat by the laws of the State, which limit the development of this type of organization to straight stock companies. An association organized on this basis in the Dover section has conducted the selling for its members very successfully, usually holding the grapes until late in the season and then selling to wine or juice factories. Large amounts of the stock are hauled in wagons and trucks to the Cleveland market, which is a heavy grape consumer. In fact, nearly all the large cities of the State receive some of their supplies from near-by growers, who sell direct to jobbers on the "street."

The distribution of Ohio shipments, most of which originate in the Unionville section, is extremely narrow. In 1918 shipments went to only seven different cities in Ohio, though 1 car each went to three neighboring cities situated in Indiana, Michigan, and Pennsylvania.

THE MIDDLE WEST.

LOCATION OF PRODUCING SECTIONS.

In several scattered sections of the middle western territory, grape growing is a specialized industry, but nowhere does it assume the importance that it reaches in New York, Michigan, Pennsylvania, or Ohio. In the Missouri Valley section, which comprises those parts of Buchanan County, Mo., Doniphan County, Kans., Pottawattamie County, Iowa, and Douglas County, Nebr., adjacent to the river, the grape industry of the Middle West reaches its highest commercial development, with the Ozark section of Washington County, Ark., and Newton County, Mo., and the independent sections of Lee County, Iowa, and Taney County, Mo., next in order of importance. Grapes are grown to some extent in practically all parts of the Middle West, but in few sections, other than those named above, does the industry assume much more than garden proportions.

Table 8 shows the loading of full cars at the various stations throughout this territory as reported to the Bureau of Markets by the various originating railroads.

TABLE 8.—*Carloadings of grapes by States in the Middle West.*

	1916	1917	1918	1919		1916	1917	1918	1919
MISSOURI.					IOWA.				
Andrew Co., Sept.: Amazonia.....	1	1	1	17	Des Moines Co., Aug.: Burlington.....	0	0	1	0
Buchanan Co., Aug.- Sept.: St. Joseph.....	17	14	1	0	Harrison Co., Sept.: Missouri Valley.....	2	0	0	0
Newton Co., Aug.: Neosho.....	3	9	3	21	Mondamin.....	2	0	0	0
Stark City.....	0	1	0	0	Harrison Co. total..	4	0	0	0
Newton Co. total..	3	10	3	21	Keokuk Co., Sept.: Gibson.....	1	0	0	0
Taney Co., Aug.-Sept.: Hollister.....	16	8	12	5	Lee Co., Aug.-Sept.: Fort Madison.....	2	12	1	1
Melva.....	0	0	9	0	Keokuk.....	1	1	0	0
Taney Co. total.....	16	8	21	5	Montrose.....	57	42	51	102
Missouri State total.	37	33	26	43	Sandusky.....	0	1	0	0
KANSAS.					Lee Co. total.....	60	56	52	103
Doniphan Co., Aug.-Sept.: Blair.....	1	1	1	0	Pottawattamie Co., Aug.- Sept.: Council Bluffs.....	77	26	2	53
Wathena.....	29	37	11	33	Wapello Co., Sept.: Ottumwa.....	1	1	0	0
Doniphan Co. total.	30	38	12	33	Unknown.....	0	3	13	0
Unknown.....	0	1	2	0	Iowa State total....	143	86	68	156
Kansas State total..	30	39	14	33	TENNESSEE.				
NEBRASKA.					Sumner Co., Aug.: Hendersonville.....	1	0	0	0
Douglas Co., Aug.-Oct.: De Bolt Place.....	3	0	0	0	ARKANSAS.				
Florence.....	28	0	0	0	Franklin Co., Aug.: Altus.....	3	0	0	0
Omaha.....	56	2	2	4	Sevier Co., Aug.: Gillham.....	0	0	0	1
Douglas Co. total..	87	2	2	4	Washington Co., Aug.- Sept.: Springdale.....	0	0	0	15
Nemaha Co., Aug.: Brownsville.....	2	2	0	8	Tontitown.....	12	0	0	0
Julian.....	1	0	0	0	Washington Co. total.....	12	0	0	15
Nemaha Co. total..	3	2	0	8	Unknown.....	0	8	9	0
Unknown.....	23	4	0	0	Arkansas State total	15	8	9	16
Nebraska State total	113	8	2	12					

ACREAGE AND VARIETIES.

The standard varieties are the Concord, the Worden, and the Moore Early, but a small acreage of almost all the other leading varieties is found. As usual, the Concord leads, comprising from 75 to 85 per cent of the shipments. As this is preeminently an early section, the best prices usually being realized before the Michigan crop comes on with its heavy shipments, there is a large proportion of the early varieties, and the Worden and the Moore assume a greater relative importance than in New York or Michigan. The date of ripening varies somewhat in this section because of the difference in latitude, but the main shipping season of the Moore Early and the Worden is from the middle of August to the first week in

September. The Concord generally begins to move heavily about September 1 and is usually cleaning up in the third week. In a normal season the heaviest shipments are between September 10 and 18.

No definite, up-to-date figures on the commercial acreages in this section are available, but a comparison of the carlot shipments from these four States (see Table 1) with the shipments of New York and Michigan will show the position it holds in the industry. The severe winters of 1916-17 and of 1917-18 played havoc with the vineyards in the northern part of this territory. The acreage in the section of Council Bluffs and Omaha is at present only about 35 per cent of that of three years ago. However, many vineyards are being replanted, so that the industry in this section may, in time, reach its former importance. Farther south, along the Missouri River, in the St. Joseph-Wathena section, the damage is not so marked, as 65 per cent of the former acreage survives. In the Ozarks the industry is proving profitable and shows a steady increase in acreage, and in other sections the replantings approximate the acreage abandoned each year.

As in all such cases, these reductions of acreage served to put the industry on a firmer basis, for the vineyards receiving the best attention were the ones that survived. The average yield per acre is relatively high in the better developed sections of this territory, running from 2 to 2 $\frac{3}{4}$ tons per acre in a good crop year along the Missouri River and from 1 $\frac{3}{4}$ to 2 $\frac{1}{2}$ tons per acre in the Ozark section.

USUAL METHODS OF SALE.

Less-than-carload shipments assume greater relative importance in this territory than in other commercial sections, as much stock is shipped on consignment to the many cities within a radius of a few hundred miles. A considerable tonnage produced near the cities of Omaha, Kansas City, or St. Louis is hauled direct to market by the farmers. The most important commercial fact about this section is that its shipments reach the markets at a time when they encounter no competition from Michigan or New York stock and at a time when the consuming public is beginning to ask for grapes. In the leading sections an f. o. b. trade has been built up and most of the carlot shipments are sold on the basis of "cash track" or of "usual terms."

In the section of Council Bluffs and Omaha the deal is practically in the growers' hands, as a cooperative association controls a large part of the acreage. In the other sections the bulk of the shipments are handled by local buyers, who, in turn, make sales on an f. o. b. basis whenever possible.

MARKET OUTLETS AND DISTRIBUTION.

The general tendency is to ship toward the North and West, but shipments commonly go as far east as Detroit and as far south as Oklahoma and Texas. Minnesota, Iowa, Kansas, Nebraska, and Missouri receive the bulk of their early supplies from the Missouri Valley and the Ozark sections, and shipments often reach points in Colorado, Montana, and the Dakotas. During 1918, a short-crop year, data furnished to the Bureau of Markets by the various originating railroads show that the shipments from Missouri, Iowa, Kansas, and Arkansas reached 13 States and 36 different cities. (See Appendix.)

THE ATLANTIC STATES.

LOCATION OF PRODUCING SECTIONS.

Grapes are grown in almost every county of the Atlantic States, but in only a few sections are they produced in quantities large enough to furnish carlot shipments. A few scattered carloads are shipped out of New Jersey, Virginia, and North Carolina, but in no eastern States except New York and Delaware does grape production assume the proportions of a specialized industry.

Table 9 shows the full carloadings at different stations throughout this territory, as reported to this bureau by the various originating railroads.

TABLE 9.—Carloadings of grapes by States in the East.

	1916	1917	1918	1919		1916	1917	1918	1919
NEW JERSEY.					VIRGINIA.				
Atlantic Co., Sept.: Landisville.....	3	0	0	0	Greensville Co., Aug.: Emporia.....	2	0	0	0
Camden Co., Sept.: Lindenwold.....	0	3	0	0	NORTH CAROLINA.				
Monmouth Co., Sept.: Hazlet.....	2	0	0	0	Martin Co., Sept.: Everetts.....	9	0	0	0
Middletown.....	0	1	1	0	Moore Co., July: Aberdeen.....	3	0	0	0
New Jersey State total.....	5	4	1	0	Southern Pines.....	1	0	0	0
DELAWARE.					North Carolina State total.....	13	0	0	0
Kent Co., Aug.-Sept.: Clayton.....	23	45	13	11					
Dover.....	0	0	11	0					
Felton.....	0	0	2	0					
Hartly.....	1	0	0	0					
Millford.....	0	1	0	0					
Wyoming.....	10	23	13	2					
Delaware State total.	34	69	39	13					

VARIETIES.

The States of Delaware and New Jersey furnish early supplies to the eastern markets. The standard varieties—the Concord, Niagara, Delaware, Catawba, Worden, and Champion—make up the bulk of the acreage; but the Ives, Wyoming, Diamond, Lindley, and Goethe

are sometimes shipped. All of these varieties are grown to a limited extent from Maine to the Gulf. Muscadine grapes are produced rather extensively in the coastal regions of Virginia and North Carolina, and to a small extent throughout the other Southern States, the Scuppernong being the best known variety.

MARKET OUTLETS.

In the New-England States the proportion of shipments to local haulings is low, as much attention is paid to the production of early fancy stock. New Jersey and Delaware growers have the important markets of Philadelphia, New York, Newark, and Baltimore practically at their doors. A large proportion of the stock sent to these markets is shipped by the growers in less than carload lots on commission, though at some of the larger shipping points in Delaware local dealers occupy a more important place in the deal. They assemble the offerings of the growers in carload lots and ship them to large terminal markets, and are thus enabled to secure a wider distribution than by less than carload shipments. It is estimated that the acreage in Delaware has been reduced between 30 and 50 per cent during recent years. The Muscadine deal in the South constitutes a unique development that does not fall within the scope of this study.

THE NORTHWEST.

Many of the attempts to grow grapes in the Northwest have resulted in failure, but the industry has become well established in several localities, especially in the Yakima Valley.

Table 10 shows the full carloadings at different stations as reported to this bureau by the various originating railroads.

TABLE 10.—*Carloadings of grapes by States in the Northwest.*

	1916	1917	1918	1919		1916	1917	1918	1919
WASHINGTON.					WASHINGTON—contd.				
Benton Co., Sept.:					Unknown.....	0	0	25	0
Kennewick.....	1	0	1	0	Washington State				
Prosser.....	0	0	6	10	total.....	30	36	59	61
Vista.....	0	2	0	0	IDAHO.				
Benton Co. total.....	1	2	7	10	Gem Co., Sept.-Oct.:				
Snohomish Co., Sept.:					Emmett.....	0	5	4	3
Everett.....	0	0	0	1	Bannock Co., Oct.:				
Walla Walla Co., Sept.-					Pocatello.....	0	1	0	0
Oct.:					Idaho State total.....	0	6	4	3
Wallula.....	0	2	0	0	OREGON.				
Wheaton Co., Aug.-Oct.:					Josephine Co., Oct.:				
Grandview.....	0	15	5	13	Grants Pass.....	0	2	0	3
Yakima Co., Oct.:					Unknown.....	0	0	2	0
Granger.....	5	4	8	12	Lane Co., Oct.:				
Selah.....	6	5	3	1	Eugene.....	0	0	1	0
Sunnyside.....	0	0	0	5	Umatilla Co., Oct.:				
Wapato.....	0	0	3	4	Hermiston.....	0	0	0	1
Yakima.....	17	7	7	11	Oregon State total.....	0	2	3	4
Zillah.....	1	1	1	4					
	29	17	22	37					

As far as the American grape industry goes, the Northwest is self-sufficing, as very few shipments from the outside go into this section and practically all of the stock produced in Washington, Idaho, and Oregon is consumed within the borders of those States.

As in other important American grape-growing sections, the Concord is the leading variety, but the Niagara, Delaware, Goethe, and Catawba are also found, the Catawba extending southward into California. Because the large city markets in this section are far removed from any other section which ships American grapes, outside competition is eliminated and the local stock moves easily at satisfactory prices.

The great bulk of the shipments consist of table stock, which is usually shipped in 4-quart Climax baskets, but a juice factory located at Kennewick, Wash., offers an outlet for much local stock and also receives carlot shipments.

MARKET PREFERENCE.

It is a well-recognized fact that different markets often have wide divergent preferences both as to container and as to varieties of the stock they demand, and as the shipment of table grapes will undoubtedly be increased by the suspension of wine manufacture, the preferences of various markets become an important subject to growers and shippers. This preference is usually the result of custom, in that the trade and the consumer have become accustomed to purchase certain varieties in certain-sized containers and will not purchase stock with which they are not familiar, except at a discount. Whether the quantity of bulk stock used in the consuming centers will continue to bear the same relation to the movement of table stock that it has in the past, is highly problematical.

Chicago is, next to New York, probably the heaviest individual receiver of eastern grapes, and the bulk stock passing through this market has nearly equaled the amount of table stock. By far the heaviest receipts upon this market are of Michigan stock, much of which is shipped in by water. Undoubtedly the fact that Michigan uses 4-quart baskets almost exclusively for table stock has led to a marked preference for that type of container, so that the 2-quart package is in very poor demand on this market and sells much below the usual proportionate price of these two sizes in other cities. The standard blue varieties, the Champion, the Moore, and the Concord, are the favorites, in season, the first named selling at the usual marked discount when in competition with other varieties. The Delaware and the Niagara meet a good but very limited demand and command a slight premium when in light supply, which is quickly wiped out by the arrival of any considerable quantity. This

market appreciates stock of good appearance and makes more distinction between labeled and unlabeled stock than most cities. New York grapes generally command a slight premium over Michigan grapes of the same class.

Pittsburgh has been an important distributing center for bulk stock, particularly that originating in the Chautauqua-Erie belt. A strong preference exists for 4-quart and 12-quart baskets, the latter having been used almost exclusively for wine, which in this district was mostly homemade. This market makes little or no distinction between varieties, except that it is markedly indifferent to the Catawba, which can scarcely be moved in any volume. New York stock generally receives a slight premium here.

The New York city market receives more varieties and types of containers than any other. Two-quart and 4-quart baskets for table stock, 12-quart baskets and return trays for bulk stock, are all in good demand, but the gift case is most easily moved. Probably because New York has received heavy supplies of various varieties from the Hudson Valley and Central Lakes districts of the State, the trade and consumers have learned the use of the different kinds, so that there is very little price differential between the Concord, Niagara, Delaware, and Catawba. The Champion and the Moore Early generally sell at a slight discount. The demand for Catawbas is not good until the other varieties are gone; then they can be moved in relatively large quantities.

Philadelphia has been a heavy receiver of bulk stock, most of which went into wine; the ratio of this type of stock to table stock has been about $2\frac{1}{2}$ to 1. For table stock the 2-quart basket is much preferred, and the 4-quart package sells below the usual proportionate price of these two sizes in other cities. The Concord is the most popular grape and commands a premium over the Niagara and the Delaware if the latter are present in large quantities. Philadelphia is not a Catawba market and it is difficult to move this variety.

Boston is a good market for fancy stock. Delawares generally command a premium of 0.5 to 1 cent per basket, though the Niagaras usually bring less than Concords until late in the season when the former variety is disappearing. It is said that there has been no demand for the Catawbas except for wine-making purposes. This market is partial to both 2-quart and 4-quart baskets, and these containers usually sell at about the average proportionate price.

Baltimore and Washington are similar in their market preferences. They are predominately table-stock consumers and demand the 2-quart package. The demand for bulk grapes is relatively limited, and it is rather difficult to move any large number of 4-quart baskets. In normal years the Niagara commands a premium of 1 to

2 cents on a small basket over the Concord, and the Delaware a premium of 2 to 3 cents. There is usually a good demand for Catawbas, especially when the Concords grow scarce. The Appendix gives no adequate idea of the importance of these two markets, both of which were undersupplied in 1918.

Cleveland and Buffalo have similar market preferences, both being located near important producing sections and receiving the majority of their supplies by local haulings in wagons and motor trucks. The former city has a preference for the 2-quart baskets, but Buffalo makes no great distinction between 2-quart and 4-quart baskets. Both cities have been heavy consumers of bulk stock, and Cleveland is interested in the grape-preserve industry. These two cities use various varieties; the Delaware usually commands a marked premium over the Concord, the Niagara a slight premium; the demand for the Catawba is good, especially late in the season.

Minneapolis, St. Paul, and Fargo are good markets for grapes, and their consumption of table stock is relatively large. The standard varieties are the Champion, the Moore, and the Concord. The Concord generally commands a premium of 3 to 5 cents per 4-quart basket when in competition with the others. For blue varieties, the great majority of which are shipped from Michigan, the 4-quart basket is the standard container, though the 2-quart is the accepted container for Catawbas, which meet only a fair demand in these cities.

Detroit receives the bulk of its supplies from the neighboring Michigan producing sections and has therefore become accustomed to the use of blue varieties in 4-quart baskets and has developed a preference for this class of stock. However, sometimes, as in 1918, New York Concords, packed in 2-quart baskets, when in competition with Michigan stock in fours, sells above the usual proportionate price of these two sizes in other cities. A limited amount of the Delaware and the Niagara usually command a slight premium, which is quickly wiped out by any increased quantity of these varieties. The Catawba finds a very limited demand in this market, until late in the season, at which time this variety can be moved in moderate quantities.

Cincinnati, Columbus, and Indianapolis receive their early supplies almost exclusively from Michigan and their late supplies from New York. Therefore there is a marked preference for the blue varieties—the Champion, the Moore, and the Concord—in 4-quart baskets, and for the later red varieties, such as the Delaware and the Catawba, in 2-quart baskets. The demand for the Catawba is fairly good, especially in Indianapolis, where this variety commands a premium of several cents per 2-quart basket even over the Concord.

St. Louis, Kansas City, Des Moines, Oklahoma City, Omaha, and Denver receive considerable home-grown stock very early in the season, but the larger part of their supply is furnished by Michigan. The standard blue varieties packed in 4-quart baskets are desired by the trade, and little other stock appears on these markets. A very limited quantity of Catawbas may be moved late in the season.

In the southern markets—Jacksonville, Atlanta, Birmingham, Memphis, Fort Worth, Dallas, Houston, and New Orleans—there is no marked preference between the 2-quart and 4-quart baskets. Shipments to these cities, shown in the Appendix, give no adequate idea of their consuming capacity, as the short crop of 1918 restricted the distribution to markets nearer the producing sections. None of these markets can stand heavy receipts without a proportionately marked drop in prices, but in the aggregate they represent an important outlet which should receive more attention. While the Concord is the most popular grape in these cities, there is not so much prejudice against red varieties as there is farther north.

In the cities of the far West—Spokane, Seattle, Portland, Butte, San Francisco, and Los Angeles—the receipts of grapes of European varieties from California far exceed those of American varieties or Eastern grapes. However, some Catawbas are raised in California and find their way into the markets of Los Angeles and San Francisco, usually in 4-basket crates, and the other cities are supplied by Washington with the Concord type of grapes. While Michigan grapes have been shipped to the more northern of these cities, the great bulk of the arrivals in Portland, Spokane, Seattle, and Butte are shipped from neighboring producing sections, principally the Yakima Valley. The Concord is the favorite grape of this type in these markets, though other varieties usually sell well, and the 4-quart basket is the common container, except in Portland, where 2-quart baskets are used almost exclusively.

DISTRIBUTION.

THE PRINCIPLES.

No phase of marketing perishable products is more important, or holds greater possibilities for improvement, than the distribution of shipments. It should be the aim of all shippers to supply adequately the demand in neighboring consuming centers, up to the point where further supplies would cause disastrous clogging of the channels of trade. At this point or, under ideal conditions, just before this point is reached, shipments would be made to other cities more distant from the point of origin, even though higher freight rates render such shipments relatively less profitable.

THE PRACTICES.

Until comparatively recent years indiscriminate consignment to the nearest large cities was the rule, but with the development of f. o. b. selling, much more attention is rightly being paid to the 1, 2, and 3 car towns. The table given in the Appendix shows the present stage of this development. A study of the relative populations in the different destinations, shown in this table, will reveal the fact that some markets are relatively oversupplied and others greatly undersupplied, but it will be noticed also that this situation seems to bear definite relation to the distance of these centers of population from the producing sections supplying them. For example, in 1918 Baltimore, a city of over 500,000 population, received 24 cars of grapes, while Cleveland, which is only slightly larger, received 75 straight cars, besides heavy less-than-carload receipts and local haulings.

CONCLUSION.

A careful consideration of the facts presented in this study will convince the thoughtful reader that there is no universal panacea for marketing difficulties. Success in marketing the grape crop can come only when all those connected with the industry work efficiently in the production, preparation, and distribution of their product.

The vineyardist should devote his attention to the production of the varieties demanded by the trade in his section, should guard against picking his crop either too early or too late, should pay particular attention to putting out a good, full, honest pack, free from diseased berries or clusters, and should choose his marketing agency, be it local buyer, grape-juice factory, or cooperative association, with care and with due consideration of the relative economic efficiency of these various types of factors.

The shipper should devote special attention to the intensive and extensive distribution of the crop, should supply the various markets with the varieties in the containers they require, and should do everything in his power to prevent inequalities in the supply on the various terminal markets.

The city handlers, of all the various types from carlot receiver to retailer, should strive to effect the uninterrupted passage of the grapes from car door to the consumer and should make special efforts to increase the consumptive demand when supplies begin to accumulate.

If these most fundamental principles are carefully followed, and they are being followed more and more every year, there is no reason why the grape industry should not continue to be a very profitable one to all concerned.

APPENDIX.

DESTINATIONS OF GRAPES.

The data here given are compiled from the daily reports of shipments made by the carriers in connection with the telegraphic market news service of the Bureau of Markets. In the case of grapes, the practice of diverting en route is relatively so limited that no provisions were made to record the changes from the original billing, but it is doubted if this will seriously affect the accuracy of these statistics. The unit in the following table is a full carload, which varies from 18,000 to 25,000 pounds. The shipments to each city are segregated by States, and, in some cases, as in New York, by sections. Centers of grape-juice factory production, where it is probable that the great majority of the receipts were used for that purpose, are indicated by a star (*), as *Brockport. The receiving markets are listed alphabetically in the first column of the table, while the producing areas, in which the shipments originated, are given at the heads of the vertical columns. The total number of cars destined to each market appears in the column at the extreme right.

Destinations of carlot shipments of eastern grapes from each important producing section.

Destination.	New York, Ontario shore.	New York-Pennsylvania, Chautauqua-Erie belt.	New York, Central Lakes.	New York, Hudson River.	Michigan.	Ohio.	Kansas.	Iowa.	Arkansas.	Missouri.	Delaware.	Washington.	Others.	Total.
Aberdeen, S. Dak.					2			2						10
Akron, Ohio.		5			2									7
Albany, N. Y.			5	29										34
Albert Lea, Minn.					3									3
Allentown, Pa.		1	13											14
Altoona, Pa.											2			2
Amarillo, Tex.					3									3
Amsterdam, N. Y.				4										4
Anderson, Ind.					2									2
Appleton, Wis.					4									4
Ashland, Wis.					4									4
Ashtabula, Ohio.		2												2
Atchison, Kans.					1									1
Atlanta, Ga.					1									1
Auburn, Me.			1											1
Augusta, Ga.					1									1
Aurora, Ill.		1												1
Austin, Minn.					2									1
Austin, Tex.					1									1

Destinations of carlot shipments of eastern grapes from each important producing section—Continued.

Destination.	New York, Ontario shore.	New York-Pennsylvania, Chautauqua-Erie belt.	New York, Central Lakes.	New York, Hudson River.	Michigan.	Ohio.	Kansas.	Iowa.	Arkansas.	Missouri.	Delaware.	Washington.	Others.	Total.
Detroit, Mich.		17	2		89	1								109
Devils Lake, N. Dak.					2									2
Dubois, Pa.		7												7
Dubuque, Iowa					2									2
Duluth, Minn.					24			4						28
Dunkirk, N. Y.		1												1
Eau Claire, Wis.					1									1
Egg Harbor, N. J.			1											1
Elizabeth, N. J.			2											2
Emporia, Kans.		2												2
Enid, Okla.					1									1
Erie, Pa.		7												7
Escanaba, Mich.					1									1
Estherville, Iowa.					3									3
Evansville, Ind.					7									7
Everett, Wash.												2		2
Fairville, Pa.	1													1
Fargo, N. Dak.					15			1						16
Farrell, Pa.		2												2
Flint, Mich.					4									4
Forest City, Pa.		1												1
Fort Dodge, Iowa					4									4
Fort Scott, Kans.					1									1
Fort Smith, Ark.					3					4				7
Fostoria, Ohio.		1												1
*Fredonia, N. Y.		22												22
Freeport, Ill.					3									3
*Fremont, Ohio					5	2								7
Fulton, N. Y.		1												1
Geneseo, N. Y.			2											2
Germantown, Ohio.		3												3
Glasgow, Mont.												1		1
Glenns Falls, N. Y.				2										2
Grand Forks, N. Dak.					8			3						11
Grand Island, Nebr.					13		4	2						19
Grand Junction, Colo.												1		1
Grand Rapids, Mich.					1									1
Great Falls, Mont.								1				1		2
Green Bay, Wis.					5									5
Greensboro, N. C.			5											5
Greensburg, Pa.		2												2
Greenville, Pa.		2												2
Guthrie, Okla.					1									1
Hammond, Ind.					10									10
Hancock, Mich.					5									5
Hannibal, Mo.					2									2
Harrisburg, Pa.			3		1									4
Harrisonburg, Ill.					1									1
Hartford, Conn.			3											3
Hastings, Nebr.					4									4
Haverhill, Mass.		1												1
Hays, Kans.					1									1
Hazleton, Pa.		2												2
Helena, Mont.					2									2
Henrietta, Mo.					1									1
Hermie, Pa.		1												1
High, Iowa.														1
*Highland, N. Y.		36	36											72
Hinton, W. Va.					2									2
Holdridge, Nebr.					1									1
Houghton, Iowa.					1									1
Huntington, W. Va.			4		2									6
Hurley, Wis.					1									1
Huron, S. Dak.					4									4
Hutchinson, Kans.					10			1						11
Idaho Falls, Idaho.													1	1
Independence, Kans.					2					1				3
Indianapolis, Ind.		8	2		55									65
Ironwood, Mich.					1									1

Destinations of carlot shipments of eastern grapes from each important producing section—Continued.

Destination.	New York, Ontario shore.	New York-Pennsylvania, Chautauqua-Erie belt.	New York, Central Lakes.	New York, Hudson River.	Michigan.	Ohio.	Kansas.	Iowa.	Arkansas.	Missouri.	Delaware.	Washington.	Others.	Total.
Ithaca, N. Y.			1											1
Jacksonville, Fla.					1									1
Jersey City, N. J.		10												10
Johnstown, Pa.		8												8
Joliet, Ill.					1									1
Joplin, Mo.		1			3									4
Kane, Mo.		3												3
Kansas City, Mo.			1		20		2			10				33
*Kennewick, Wash.											11			11
Kensington, Kans.					2									2
Keystone, W. Va.					1									1
Kingston, N. Y.			1											1
Knoxville, Tenn.		1			1									2
LaCrosse, Wis.					6			1						7
Lansing, Mich.					1									1
*Lawton, Mich.					17									17
Lincoln, Nebr.					22									22
Little Falls, N. Y.		1							1	2				4
Little Rock, Ark.					9				2	2				13
Livingston, Mont.												1		1
Logansport, Ind.					2									2
Louisville, Ky.		3	4		23									30
Lynchburg, Va.		1	4											5
McCalister, Okla.					4			2						6
McKeesport, Pa.		1												1
McPherson, Kans.					1									1
Madison, Wis.					4									4
Malone, N. Y.				2										2
Manchester, N. H.				1										1
Manchester, N. Y.			1											1
Manhattan, Kans.					1									1
Mankato, Minn.					9									9
Marion, Ohio.			1		2									3
Marshalltown, Iowa.					2									2
Marshfield, Wis.					4									4
Mason City, Iowa.					5			5						10
*Mattewan, Mich.					11									11
Meadville, Pa.		2												2
Memphis, Tenn.		28			3									31
Menominee, Mich.					5									5
Middletown, N. Y.		1		2										3
Milwaukee, Wis.	3	2	2		53									60
Minneapolis, Minn.		2	2		114			18		2		1		137
Minot, N. Dak.					5									5
Mitchell, S. Dak.					5									5
Montclair, N. J.		1	1	2										4
Mount Carmel, Pa.			1											1
Muskogee, Okla.					2									2
Nashville, Tenn.			1		5									6
Newark, N. J.		9	41	1	1									52
New Britain, Conn.			4											4
New Bedford, Mass.				3										3
New Castle, Pa.		5												5
New Richmond, Ohio.			1											1
New York, N. Y.	3	46	50	320	4									423
Nottingham, Ohio.						1								1
North Adams, Mass.			3	5										8
*North East, Pa.		54			20									74
Ogdensburg, N. Y.		1	1	3										5
Oil City, Pa.		3												3
Oklahoma City, Okla.					9				1					10
Olean, N. Y.		5												5
Oelwein, Iowa.					10			1						11
Omaha, Nebr.					31									31
Oshkosh, Wis.					4									4
Ottawa, Kans.					1									1
Ottumwa, Iowa.					2									2
Painesville, Ohio.		1												1
Palmerton, Pa.		2												2
Paris, Ill.					2									2

Destinations of carlot shipments of eastern grapes from each important producing section—Continued.

Destination.	New York, Ontario shore.	New York-Pennsylvania, Chautauqua-Erie belt.	New York, Central Lakes.	New York, Hudson River.	Michigan.	Ohio.	Kansas.	Iowa.	Arkansas.	Missouri.	Delaware.	Washington.	Others.	Total.
Parsons, Kans.					2									2
Passaic, N. J.			5											5
Paterson, N. J.			8											8
Peckville, Pa.			3											3
Peoria, Ill.		2												2
Petersburg, Va.			1											1
Philadelphia, Pa.	3	59	65	2							18			147
Pipestone, Minn.					1									1
Pittsburg, Kans.		1			2									3
Pittsburgh, Pa.	12	217	21		37						5			292
Pittsfield, Mass.		1												1
Pocatello, Idaho.					1							1		2
Portland, Me.			6	5										11
Portland, Oreg.													2	2
Providence, R. I.		9	5	6										20
Pueblo, Colo.					8									8
Racine, Wis.					2									2
Reading, Pa.			3											3
Ridgeway, Pa.		1												1
Richland, Pa.		1												1
Richmond, Va.		1	13											14
*Ripley, N. Y.		13												13
Rochester, Minn.					4									4
*Rochester, N. Y.	1		35											36
Rockford, Ill.					3									3
Roslyn, Wash.												1		1
Rugby, N. Dak.					1									1
Rutland, Vt.				1										1
Saco, Me.				1										1
St. Joseph, Mo.					2		1							3
St. Louis, Mo.			1		58									61
St. Paul, Minn.					25			6						31
Salina, Kans.					8			1						9
Salt Lake City, Utah												1		1
*Sandusky, Ohio		2	1			6								9
Savannah, Ga.			1											1
Savona, N. Y.			1											1
Schenectady, N. Y.		2		5										7
Scotts Bluff, Nebr.								1						1
Scottsburg, Nebr.					1									1
Scranton, Pa.			8											8
Seaside, N. J.		2												2
Seattle, Wash.												12		12
Sharon, Pa.		3												3
Shawnee, Okla.					1									1
Sheboygan, Wis.					2									2
Sheridan, Wyo.					2									2
*Silver Creek, N. Y.		2												2
Sioux City, Iowa					25									25
Sioux Falls, S. Dak.					9			5		1				14
Smithers, W. Va.					1									1
Smithfield, Ohio						1								1
South Bend, Ind.					1									1
South Bethlehem, Pa.	1	2	2											5
Southern Junction, Ill.					2									2
Spartanburg, S. C.			1											1
Spencer, Iowa					5									5
Spokane, Wash.												13		13
Springfield, Ill.		1			3									4
Springfield, Mass.	1	7	3	4										15
Steelton, Pa.		1	7											8
Sterling, Ill.					1									1
Stevens Point, Wis.					1									1
Stony Island, Ill.		1												1
Superior, Wis.					5									5
Syracuse, N. Y.		1	1	7										9
Tacoma, Wash.												1		1
Terre Haute, Ind.														2
Toledo, Ohio			4		10	2								16

*Destinations of carlot shipments of eastern grapes from each important
producing section—Continued.*

Destination.	New York, Ontario shore.	New York-Pennsylvania, Chautauque-Erie belt.	New York, Central Lakes.	New York, Hudson River.	Michigan.	Ohio.	Kansas.	Iowa.	Arkansas.	Missouri.	Delaware.	Washington.	Others.	Total.
Topeka, Kans.					9			1	1	1				12
Tracey, Minn.					2									2
Trenton, N. J.			1											1
Trinidad, Colo.		2			1									3
Troy, N. Y.			1											1
Tulsa, Okla.					8			3						11
Tyrone, Pa.		1	2											3
Underwood, W. Va.			1											1
Utica, N. Y.	1	2	13	34	2									50
Valley City, N. Dak.				1										2
Voorheesville, N. Y.					1									1
Wabash, Ind.					1									1
Wahpeton, N. Dak.					2									2
Warren, Pa.		1				1								2
Warsaw, Ind.					2									2
Washington, D. C.		4	21											25
Waterloo, Iowa.					7			1						8
Waterloo, N. Y.		1	1											1
Watertown, N. Y.		1	7	2										10
Watertown, Wis.					5									5
Watkins, N. Y.			3	1										4
Watuppa, Mass.				1	1									1
Weehawken, N. J.			1	1										2
Wellington, Kans.					1									1
Westalon, Mo.		1												1
Westfield, N. Y.		172												172
Wichita, Kans.					16									16
Wick Haven, Pa.		1												1
Wickliffe, Ohio.						1								1
Wilkes-Barre, Pa.		2												2
Winner, Kans.							1							1
Winona, Minn.					8									8
Winona, Ohio.		1												1
Winston-Salem, N. C.			1											1
Winton, Pa.			1											1
Worcester, Mass.			3	3										6
Yakima, Wash.												5		5
Yonkers, N. Y.				1										1
Yorktown, Ind.					1									1
Youngstown, Ohio.		14												14
Yukon, Pa.		1												1
Zionville, N. C.					1									1
Unknown.	39	6	28	0	49	5	0	0	0	5	14	1	63	152
Total.	66	1,089	694	573	1,637	54	14	68	9	26	39	59	9	4,338

RECAPITULATION OF DESTINATION BY STATES.

Alabama					1									1
Arkansas					12				6	2				20
Connecticut		3	7											10
Colorado		9	2		29		4			1		1		46
District of Columbia		4	21											25
Florida					1									1
Georgia			1		2									3
Idaho					1									1
Illinois					368							1	2	4
Indiana		38	3		83	1				1				410
Iowa		82	2		92			13		1				94
Kansas		32	2		60		3	3		2				108
Kentucky		3	4		23									30
Maine				6										13
Maryland		5	21		1									27
Massachusetts	1	101	50	135	1								1	289
Michigan		17	2		141	1								161

a Includes 3 from Idaho (destination unknown).

Destinations of carlot shipments of eastern grapes from each important producing section—Continued.

RECAPITULATION OF DESTINATION BY STATES—Continued.

Destination.	New York, Ontario shore.	New York-Pennsylvania, Chautauqua-Erie belt.	New York, Central Lakes.	New York, Hudson River.	Michigan.	Ohio.	Kansas.	Iowa.	Arkansas.	Missouri.	Delaware.	Washington.	Others.	Total.
Minnesota.....		2	2		193			23		2		1		226
Missouri.....		2	2		87		3	2		10				106
Montana.....					2			1				7		10
Nebraska.....			1		75		4	3	1	2				86
New Hampshire.....				1										1
New Jersey.....		13	71	4	1									89
New York.....	6	362	268	418	5									1,059
North Carolina.....			6		1									7
North Dakota.....					37			5				1		43
Ohio.....		55	21		117	46								239
Oklahoma.....					27			5	1					33
Oregon.....													2	2
Pennsylvania.....	17	410	134	2	58	1					25			647
Rhode Island.....		9	5	6										20
South Carolina.....			9											9
South Dakota.....					30			7						37
Tennessee.....		29	1		8									38
Texas.....					4									4
Utah.....												1		1
Vermont.....			3	1										4
Virginia.....		2	18											20
Washington.....												46		46
West Virginia.....		6	3		19									28
Wisconsin.....	3	2	2		101			1						109
Wyoming.....					8									8

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E. W. NELSON, Chief



Washington, D. C.

PROFESSIONAL PAPER.

December 30, 1920

FOOD HABITS OF SEVEN SPECIES OF AMERICAN SHOAL-WATER DUCKS.

By DOUGLAS C. MABBOTT,¹ *Assistant in Economic Ornithology.*

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INTRODUCTION.

The wild ducks of the United States belong to three main groups: The mergansers (Merginae), known also as fish ducks or sawbills; the river ducks (Anatinae), called also shoal-water, puddle, plash, or tipping ducks; and the sea ducks (Fuligulinae), otherwise known as deep-water or diving ducks. This bulletin treats of the food habits of eight species² of shoal-water ducks, one of which, the European widgeon, is only a straggler in the United States. Wild ducks are our most important game birds, their value to the people of the

¹ Douglas Clifford Mabbott, author of this bulletin, was a member of the heroic Sixth Regiment, United States Marine Corps, and participated in all the hard fighting done by that organization at Boursesches, Belleau Wood, Soissons, and in the St. Mihiel salient. He was killed in action September 15, 1918, while taking part in an advance in the battle of St. Mihiel, and was buried near the village of Xammie, near Thiaucourt, France. He was born at Arena, Wis., March 12, 1893, and became a member of the staff of the Biological Survey, December 1, 1915.—EDITOR.

² Three other species, the mallard, black duck, and southern black duck, are treated in Bull. 720, U. S. Dept. Agr., Food Habits of the Mallard Ducks of the United States, by W. L. McAtee, pp. 35, pl. 1, Dec. 23, 1918.

NOTE.—This bulletin presents a technical study of the food habits of seven species of American shoal-water ducks: The gadwall, the baldpate, the green-winged, blue-winged, and cinnamon teals, the pintail and the wood duck; and includes a brief note on the European widgeon, which is a straggler in the United States. The vegetable food preferences exhibited will serve as guide to certain wild-duck foods that may be propagated when it is sought to increase the numbers of these valuable game ducks either in the wild state or in domestication. For specific information on this topic, see Bull. 205, U. S. Dept. Agr., Eleven Important Wild-duck Foods, in which are discussed musk grass, duckweeds, frogbit, thalia, water elm, swamp privet, eelgrass, widgeon grass, watercress, waterweed, and coontail; pp. 25, figs. 23, May 20, 1915; also Bull. 465, Propagation of Wild-duck Foods, in which are discussed wild rice, wild celery, pondweeds, delta potato, wapato, chufa, wild millet, and banana waterlily; pp. 40, figs. 35, Feb. 23, 1917.

United States totaling hundreds of thousands of dollars. Some of the species covered by this bulletin are among the most valuable, as the pintail, gadwall, baldpate, and green-winged teal.

The ducks here discussed have not thus far been utilized in duck farming to so great an extent as the mallard and black ducks, but the wood duck and the green-winged teal have proved to be adapted to such use, and possibly further experiments will result as successfully with some of the other species. Information presented in the following pages shows the preferences of these ducks among vegetable foods, matters which should be heeded in attempting to establish the more or less natural conditions which probably will be found necessary for success in the propagation of some of the species in inclosures.

GADWALL.

(*Chaulelasmus streperus*.)

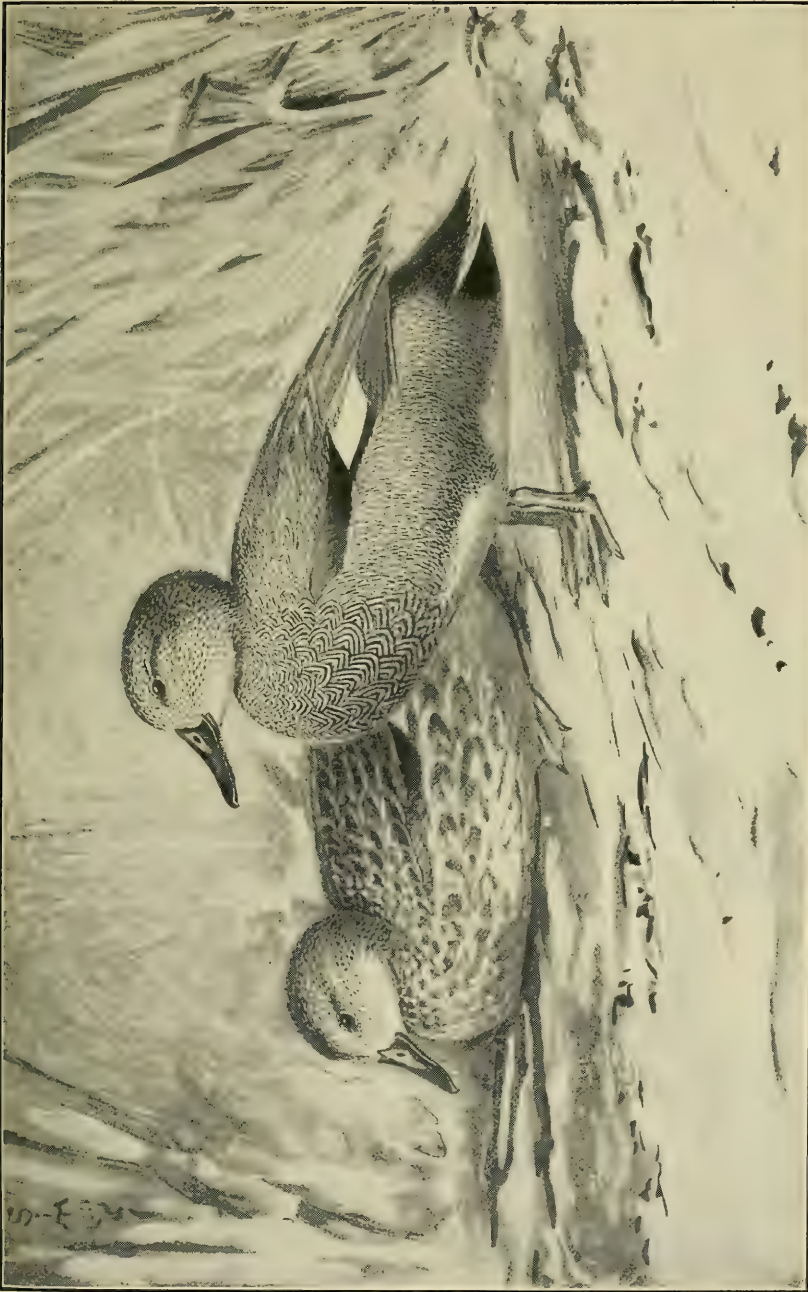
PLATE I.

The gadwall, or gray duck, as it is sometimes called, is almost cosmopolitan in its distribution, breeding commonly in Europe, Asia, and North America and ranging south in winter to southern Asia, some distance into Africa, and in North America to the southern end of Lower California and to southern Puebla. East of the Mississippi River, however, and north of North Carolina, the bird is rare, and in New England is found only as a straggler. It breeds in most of the western United States and in southern Canada, but its principal breeding range for North America is in the prairie district extending from Manitoba and western Minnesota to the Rocky Mountains, south to Nebraska, and north to Saskatchewan.

The adult male gadwall is distinguished particularly by the scale-like markings on the breast, each feather on the lower neck and breast being black with a white crescent and a white border, producing a peculiar mottled or barred effect. The bird has a prominent white speculum or wing patch, bordered in front by black, with an area of chestnut-brown on the forepart of the wing, comprising the middle wing coverts. The remainder of the plumage is chiefly gray or brownish, streaked with black. The female lacks the chestnut wing coverts, and the breast and sides are buffy with the barred appearance less distinct.

FOOD HABITS.

In habits the gadwall resembles the mallard, feeding either on dry land or in shallow water near the edges of ponds, lakes, and streams, where it gets its food by "tilting" or standing on its head in the water. The food of both the gadwall and the baldpate, however, is quite different in some respects from that of the mallard. These two feed to a very large extent upon the leaves and stems of water



BIGGS

GADWALL (*CHAULELASMUS STREPERUS*).
Male on right; female on left.



plants, paying less attention to the seeds, while the mallard feeds indiscriminately on both or even shows some preference for the seeds. In fact, in respect to the quantity of foliage taken, the gadwall and the baldpate are different from all other ducks thus far examined by the Biological Survey. They are also more purely vegetarian, their diet including a smaller percentage of animal matter than that of any of the other ducks.

For a determination of the food habits of the gadwall 417 stomachs³ were available. These were from 19 States and Canada, and their collection extended over a period of 31 years. Only 24 were taken during the five months from April to August and their contents were not included in computing the average percentages, so that the results thus obtained apply only to the fall and winter months.

Considerably more animal food is taken in summer than in winter, owing, of course, to the fact that more is available at that time of year. The percentage of animal food for the summer months is higher also because there are included in the averages analyses of numerous stomach contents of ducklings, which feed to a great extent upon insects. All of the 11 stomachs collected during the month of July (9 from North Dakota and 2 from Utah) were of young ducklings. A computation of the average contents of this series produced the following results: Water bugs, 56.18 per cent; beetles, 7.09; flies and their larvae, 2; nymphs of dragonflies and damselflies, 0.27; other insects, 2; total animal food, 67.54 per cent. Pondweeds, 12.55 per cent; grasses, 5.09; sedges, 2; water milfoils, 0.55; smartweeds, 0.09; miscellaneous, 12.18; total vegetable food, 32.46 per cent.

Of the remaining 13 stomachs collected in summer, all but two were from mature birds. Their contents averaged 11.17 per cent animal food and 88.83 per cent vegetable; 5.28 per cent, or nearly half the animal food, consisted of snails. Thus it will be seen that, so far as can be judged from the contents of such a limited number of stomachs, the summer food of the adult birds does not differ greatly from their winter food.

A rather large proportion of the total number of stomachs (131) was from birds taken in Louisiana. These furnished the bulk of the collections for November, February, and March, but averaged much the same as those from the other States, the principal items consisting of sedges, pondweeds, *Sagittaria* tubers, grasses, some cultivated rice, and mollusks. Arkansas contributed 57 stomachs; Utah, 53; North Carolina, 30; North Dakota, 22; and Florida, 20; the remainder being scattered.

³ Seventy-six of these were examined by W. L. McAtee.

VEGETABLE FOOD.

As computed from the contents of 362 stomachs collected during the six months from September to March, 97.85 per cent of the food of the gadwall consists of vegetable matter. This is made up as follows: Pondweeds, 42.33 per cent; sedges, 19.91; algae, 10.41; coontail, 7.82; grasses, 7.59; arrowheads, 3.25; rice and other cultivated grain, 1.31; duckweeds, 0.61; smartweeds, 0.59; wild celery and waterweed, 0.53; waterlilies, 0.52; madder family, 0.37; and miscellaneous, 2.61 per cent.

PONDWEEDS (NALADACEAE), 42.33 PER CENT.

Of the 417 gadwalls whose stomachs were examined, 155 had eaten true pondweeds (*Potamogeton* spp.), 112 widgeon grass (*Ruppia maritima*), 20 horned pondweed (*Zannichellia palustris*), 17 bushy pondweed (*Najas flexilis*), 3 eelgrass (*Zostera marina*), and 8 pondweeds which were too far advanced in the process of digestion to be further identified. In nearly all cases the pondweed food consisted chiefly of leaves and stems, and sometimes buds and tubers. Seeds were often present, sometimes in considerable numbers, but as a rule they appeared to be merely incidental. Pondweeds are undoubtedly the favorite food of this species, as well as of the baldpate, and they are eaten very greedily. The gullet of one gadwall taken in Texas in November contained a mass of the foliage of small pondweed (*Potamogeton pusillus*) the size of a billiard ball. A series of 26 stomachs taken in North Carolina in December contained practically nothing but the leaves and stems of pondweeds, including true pondweeds, bushy pondweed, and widgeon grass. Many of these stomachs were crammed. Often a few of the seeds were present, and three stomachs contained in addition a few sedge seeds. Other rather large series of gizzards containing chiefly foliage of pondweeds were taken in Florida, Louisiana, Utah, and North Dakota.

SEDGES (CYPERACEAE), 19.91 PER CENT.

The sedges, second in favor among the food items of the gadwall, constitute an important exception to this bird's rule of feeding upon the leaves and stems of plants rather than upon the seeds, for the leaves and stems of practically all the sedges are coarse, fibrous, or even woody, and do not make choice morsels. On the other hand, the seeds are a favorite item of food among most fresh-water ducks. The sedge seeds most often eaten by the gadwall were those of three-square (*Scirpus americanus*), by 150 birds; prairie bulrush (*S. paludosus*), by 27; salt-marsh bulrush (*S. robustus*), by 24; unidentified bulrushes (*Scirpus* spp.), by 47; saw grass (*Cladium effusum*), by 68; and chufas (*Cyperus* spp.), by 31. A considerable number of birds from the Mississippi Delta, Louisiana, had been feeding during

January and February almost exclusively on the seeds of three-square. Some had eaten also the rootstocks of bulrushes, probably of the same species as the seeds; others from the same general region had varied their diet by feeding to some extent upon the delta potato (tubers of *Sagittaria platyphylla*), and a few snails. Bulrush seeds, however, usually constituted the bulk of the stomach contents. Several gizzards contained no fewer than 1,800 to 3,000 seeds.

ALGAE, 10.41 PER CENT.

It is not surprising that in a duck which feeds so freely upon the foliage of aquatic vegetation, algae formed more than one-tenth of the total stomach contents. These were eaten most freely in spring, the maximum consumption being 21.67 per cent of the total food for the month of March, and the minimum, 1.64 per cent in December. Most of the algae eaten consisted of musk grass (*Chara* spp.), but several other kinds were present.

COONTAIL (*Ceratophyllum demersum*), 7.82 PER CENT.

So far as known, the gadwall is the only duck which feeds to any extent upon the foliage of coontail, which gets its common name from a fancied resemblance in the shape of its finely branching stems and leaves to the tail of a raccoon. It is also called hornwort, hornweed, and morassweed. Many other species of ducks commonly feed upon the hard, horny coated seeds of the plant, but a series of 50 gadwalls taken in December, 1909, along the Mississippi River in northwestern Arkansas, had eaten large quantities of the leaves and tips of the stems, many to the exclusion of all other food.

The contents of these 50 stomachs averaged as follows: Coontail, 87.72 per cent; duckweeds, 3.88; seeds of buttonbush, 1.66; pondweeds, 1.6; algae, 1; sedges, 0.16; miscellaneous vegetable matter, 3.24; statoblasts of fresh-water bryozoa, 0.6; and water bugs, 0.14 per cent. It is possible that if stomachs of the baldpate had been available from the same region, this bird also might have shown a taste for the foliage of coontail. However, three other gadwall stomachs (one from Colorado and two from Louisiana) contained considerable quantities of the plant, while only one of the entire collection of baldpates had eaten it to an appreciable extent.

GRASSES (GRAMINEAE), 7.59 PER CENT; AND CULTIVATED GRAINS, 1.31 PER CENT.

Considerable quantities of grass were found in stomachs collected during the spring months, especially March, when the tender young shoots are plentiful throughout the greater part of the ducks' winter range. This consisted largely of the shoots and young leaves of switchgrass (*Panicum repens* and others of the same genus), but there were also present meadow grass (*Poa* sp.), saltgrass (*Distichlis spicata*),

little barley (*Hordeum pusillum*), crab grass (*Syntherisma sanguinalis*), wild millet (*Echinochloa crus-galli*), foxtail (*Chaetochloa glauca*), cut-grass (*Zizaniopsis miliacea*), rice cut-grass (*Homalocenchrus oryzoides*), salt-marsh grass (*Spartina* sp.), manna grass (*Panicularia* sp.), *Monanthochloë littoralis*, and a few others, unidentified. Several of these were represented only by the seeds, and then they usually constituted a comparatively small part of the stomach contents.

The cultivated grain was tabulated separately from the remainder of the grasses because of the economic interest attached to it. It consisted, however, almost entirely of rice found in the gizzards of several Louisiana birds taken in February, and was undoubtedly waste grain. One stomach taken in Oregon in January was crammed with grains of barley; and another, from North Carolina in February, contained several kernels of corn. Obviously these also were of no economic importance. The rice, barley, and corn together amounted to 1.31 per cent of the contents of the whole number of stomachs.

WATER PLANTAIN FAMILY (ALISMACEAE), 3.25 PER CENT.

One of the favorite items of food among many species of ducks in the lower Mississippi Valley during the fall and winter months is the delta potato, as the starchy tubers of a species of arrowhead (*Sagittaria platyphylla*) are called.⁴ These constitute an especially important food item among ducks wintering on the Mississippi Delta, Louisiana, where the tubers grow in great abundance and the variety of duck food is not great. Many gadwall stomachs from this region contained only three items of food, which also have been found to be the typical diet of several other species when wintering on the Delta: these were the seeds of three-square (*Scirpus americanus*), the delta potato, and a species of snail (*Neritina virginea*), very abundant there. The stomach contents of a series of 27 gadwalls taken near the end of the Delta in November averaged as follows: Seeds of three-square (with a few of salt-marsh bulrush), 44.55 per cent; delta potato, 20.89; pondweeds, 13.78; and snails, 7.11 per cent; several minor items, as algae, coontail, duckweeds, and a few insects made up the remainder.

DUCKWEEDS (LEMNACEAE), 0.61 PER CENT.

It is rather surprising that a duck which shows such a marked preference for the foliage of aquatic vegetation as the gadwall should not have eaten duckweeds to a greater extent. These are small floating plants, often present in such abundance in ponds, lakes, and sluggish streams as completely to cover large areas of their surfaces. The little plants are luscious and tender, and afford a favorite article of food for many species of duck. Large numbers of the gadwall

⁴ Bull. 465, U. S. Dept. Agr., pp. 21-24, 1917.

stomachs examined were collected in the swamps of Louisiana, Arkansas, and other localities where duckweeds abound, but the majority failed to disclose any duckweeds. Only 17 of the total number of ducks had eaten duckweeds (*Lemna* spp.), and some of these only in very limited quantities.

SMARTWEEDS (POLYGONACEAE), 0.59 PER CENT.

The Polygonaceae is one of the families of plants of which the seeds alone furnish an important article of food for birds. This very probably is the reason why smartweeds are only one of the minor items in the food of the gadwall. The following species were identified from the stomachs examined: Dock-leaved smartweed (*Polygonum lapathifolium*), found in 5 stomachs; water smartweed (*P. amphibium*), in 3; and knotweed (*P. aviculare*), Pennsylvania smartweed (*P. pennsylvanicum*), water pepper (*P. hydropiper*), lady's-thumb (*P. persicaria*), mild water pepper (*P. hydropiperoides*), and prickly smartweed (*P. sagittatum*), in 2 each. Seeds of black bindweed (*Polygonum convolvulus*) and another species (*P. opelousanum*) were present in 1 each, unidentified smartweeds in 2, and seeds of dock (*Rumex* spp.) in 2. Smartweed seeds were present usually in small numbers, but the gullet of one bird taken in Montana was crammed with about 3,000 seeds of water pepper, in addition to a few of dock-leaved smartweed.

FROGBIT FAMILY (HYDROCHARITACEAE), 0.53 PER CENT.

Wild celery (*Vallisneria spiralis*) was found in the stomachs of 3 birds shot on Mobile Bay, Alabama, and waterweed (*Philotria* spp.) had been eaten in generous quantity by a bird from southern Wisconsin. Wild celery is a very important food item of some species of ducks.

WATERLILY FAMILY (NYMPHAEACEAE), 0.52 PER CENT.

Two gadwall stomachs collected in Florida were filled with the seeds of a white waterlily (*Castalia* sp.), one containing about 1,100 and the other 1,200 seeds. Another from the same State contained 28 of the hard ovoid seeds of water shield (*Brasenia schreberi*).

MADDER FAMILY (RUBIACEAE), 0.37 PER CENT.

Twenty-three gadwalls had eaten seeds of buttonbush (*Cephalanthus occidentalis*). These seeds are narrowly wedge shape and are borne like miniature sycamore balls in spherical clusters on the ends of the branches of the plant, which is a shrub or small tree growing in wet places. They had been eaten by few of the ducks in any great numbers, but in some instances they constituted the greater part of the stomach contents.

MISCELLANEOUS VEGETABLE FOOD, 2.61 PER CENT.

A large number of miscellaneous items made up the remainder of the gadwall's vegetable food. The stomach of one duck from the mouth of Bear River, Utah, was filled with remains of the stems, leaves, and seeds of picklegrass (*Salicornia ambigua*). A young duck from the same region had made a meal of willow catkins (*Salix* sp.). Several gizzards from the wooded swamps of Arkansas contained fragments of scales from the cones of bald cypress (*Taxodium distichum*), and one was entirely filled with galls from cypress leaves. Many from this region also contained the seeds, or fragments of seeds, of grapes (*Vitis* sp.), hackberry (*Celtis* sp.), holly (*Ilex* sp.), and sumachs (*Rhus* spp.). Seeds of beggar ticks, or bur marigold (*Bidens* sp.), water milfoil (*Myriophyllum* sp.), bottle brush (*Hippuris vulgaris*), crowfoot (*Ranunculus* sp.), water pennywort (*Hydrocotyle* sp.), dodder (*Cuscuta* sp.), myrtle (*Myrica* sp.), bur reed (*Sparganium* sp.), heliotrope (*Heliotropium indicum*), and many others, eaten in small quantities, completed the vegetable food of the species.

ANIMAL FOOD.

As has been stated previously, the proportion of animal food taken by the gadwall is very small, amounting to only 2.15 per cent of the contents of the stomachs examined, exclusive of the few scattered items taken during the months from April to August. In these the presence of several stomachs of ducklings caused the average percentage of animal food to run considerably higher. The figures given were compiled from the contents of the 362 stomachs collected during the fall and winter months, from September to March.

MOLLUSKS (MOLLUSCA), 1.6 PER CENT.

About three-fourths of the animal food of the gadwall, or 1.6 per cent of the total, consisted of mollusks. In 6 April stomachs (not included in this average) they amounted to 15.83 per cent of the monthly food. In the fall and winter months they ranged from nothing in September to 4 per cent in January. Eight species of snails were identified, while there were unidentified fragments of snails in 5 stomachs and unidentified bivalves in 3. The most important snail was *Neritina virginea*, which is very common on the Mississippi Delta and constitutes one of the principal items of food of many species of ducks wintering in that region. This had been eaten by 25 gadwalls and ranged from a mere trace to 70 per cent of the food present.

INSECTS (INSECTA), 0.39 PER CENT.

Insects amounted to only 0.39 per cent of the total food. These consisted of caddisflies and their larvae (Phryganoidea), 0.19 per cent; flies and their larvae (Diptera), 0.07; bugs (Hemiptera), 0.05;

beetles (Coleoptera), 0.04; dragonflies and damselflies and their nymphs (Odonata), 0.01; and other insects, 0.03 per cent.

One Oregon bird had made almost a full meal of adult caddisflies in October, and the tube-shaped larval cases were found in the stomachs of 8 others.

The Diptera usually consisted of larvae or pupae, but occasionally of adult flies. Six families were represented, as follows: Crane-flies (Tipulidae), found in 1 stomach; midges (Chironomidae), in 10; soldierflies (Stratiomyidae), in 2; horseflies (Tabanidae), in 1; Borboridae, in 3; and Ephydriidae, in 8.

The bugs taken were chiefly aquatic. Water boatmen (Corixidae) had been eaten by 25 gadwalls, creeping water bugs (Naucoridae) by 6, and water striders (Gerridae) by 4, while shorebugs (Saldidae), stink bugs (Pentatomidae), and plant hoppers (Fulgoridae) were taken by 1 each.

The most common Coleoptera were water scavenger beetles (Hydrophilidae), predacious diving beetles (Dytiscidae), ground beetles (Carabidae), leaf beetles (Chrysomelidae), and weevils (Rhynchophora). Other families represented were rove beetles (Staphylinidae), larder beetles (Dermestidae), ladybugs (Coccinellidae), pill beetles (Byrrhidae), leaf chafers (Scarabaeidae), darkling beetles (Tenebrionidae), flower beetles (Anthicidae), and blister beetles (Meloidae). Of the 362 birds taken during the fall and winter months, only 23 had eaten beetles, and these never amounted to more than 4 per cent of the stomach contents. Of 11 ducklings taken in July, however, all but one had eaten beetles; in three instances these amounted to 15 per cent, and constituted 7.09 per cent of the food of all.

Two gadwalls had eaten nymphs of dragonflies (Anisoptera), two those of damselflies (Zygoptera), and one an odonate nymph, too badly ground to be identified.

The miscellaneous insects consisted of a few ants, ichneumons, etc. (Hymenoptera), and a caterpillar (Lepidoptera). Together they amounted to only 0.03 per cent.

CRUSTACEANS (CRUSTACEA), 0.08 PER CENT.

Crustaceans evidently are not much sought after by the gadwall. Twenty-one birds had eaten very small bivalved crustaceans (Ostracoda), usually in small numbers. Three gizzards contained the fingers of crabs, two the remains of crawfish, and one a sowbug (*Oniscus asellus*). Altogether, crustaceans furnished only 0.08 per cent of the gadwall's food.

MISCELLANEOUS ANIMAL FOOD, 0.08 PER CENT.

The stomach of a gadwall from an open lake in northeastern Arkansas contained several hundred of the small reproductive buds,

or statoblasts, of fresh-water Bryozoa. These are simple animal organisms which grow in colonies resembling masses of jelly, attached to submerged brush. Bits of hydroids (animals closely related to the corals) were found in 2 stomachs; spiders, in 3; water mites (Hydrachnidae), in 3; and the teeth or scales of small fish, in 2.

BALDPATE.

Mareca americana.

PLATE II.

Roughly speaking, the range of the baldpate, or American widgeon, includes practically all of North America. Its breeding range extends from Lake Michigan and Hudson Bay west to the Pacific Ocean and from Wisconsin, Colorado, and Oregon north to central Alaska, the Mackenzie Valley, and Fort Churchill. It does not breed commonly, however, east of Minnesota or south of North Dakota. Along the Atlantic Coast it is common in migration as far as Chesapeake Bay, and is only a straggler in New England and eastern Canada. In winter it is found as far south as Florida, Cuba, and Guatemala, and rarely in Costa Rica, Jamaica, Porto Rico, and Trinidad. Many individuals winter as far north as southern British Columbia, Utah, New Mexico, Illinois, and Chesapeake Bay, and a few occasionally remain in southern New England.

The adult baldpate is distinguished by the following characters: There is a large area of white on the wings in front of the speculum, which is black with a narrow green area near its front edge; the top of the head, including the forehead, is white, producing the bald appearance which gives the bird its name. Just below the "bald spot," covering each side of the head from the eye back to and including the nape of the neck, is a broad stripe of glossy green; below this the head and neck are mottled gray, the upper breast and sides pinkish brown, lower breast and belly white, under tail-coverts and outer upper tail-coverts black; the back is finely barred with black and gray or buff, and the rump is mostly white. The female lacks the white crown and green headband; the back is more coarsely mottled and streaked, and the white of the wings is less prominent.

FOOD HABITS.

The feeding habits of the baldpate are in general very similar to those of the gadwall. In some respects the similarity of the results obtained by computing the average percentages of certain elements of food in a large number of stomachs of each species is quite remarkable. For instance, the average proportion of pondweeds (*Naiadaceae*) found in the gadwall stomachs was 42.33 per cent, while in the case of the baldpate it was 42.82 per cent. There are a few slight differences in the food habits of the two species, however. The bald-



BALDPATE (*MARECA AMERICANA*).
Male on right; female on left.

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pate appears to be even less of a seed eater than the gadwall. Sedges (Cyperaceae), consisting almost entirely of seeds, amounted to 19.91 per cent of the food of the gadwall, but to only 7.41 per cent of the food of the baldpate. The baldpate also ate more wild celery (*Vallisneria spiralis*), grasses, and water milfoils (*Hippuris vulgaris* and *Myriophyllum* sp.), but much less coontail (*Ceratophyllum demersum*).

Investigation of the food habits of the baldpate consisted chiefly of an examination of the contents of 255 stomachs,⁵ collected (all but 4) during the months from September to April, inclusive, from 25 States, 4 Canadian Provinces, Alaska, and Mexico. With the exception of series of 53 from Utah, 50 from Oregon, and 29 from North Carolina, they were very evenly distributed in numbers among the different States and Provinces. Four stomachs of birds shot in May and June, together with 22 others which were too nearly empty to allow accurate estimates of percentages of food contents, were not included in the computation, so that the results given are from the remaining 229 stomachs. In the list of food items, however, material from all stomachs is included.

VEGETABLE FOOD.

The vegetable food of the baldpate for the 8 months from September to April averaged 93.23 per cent. This consisted of the following items in the order of their importance: Pondweeds, 42.82 per cent; grasses, 13.9; algae, 7.71; sedges, 7.41; wild celery and waterweed, 5.75; water milfoils, 3.48; duckweeds, 2.2; smartweeds, 1.47; arrow-grass, 0.36; waterlilies, 0.26; coontail, 0.24; and miscellaneous, 7.63 per cent.

PONDWEEDS (NAIADACEAE), 42.82 PER CENT.

Pondweeds are by far the most important item of food of the baldpate, as well as of the gadwall and several other species of ducks. Of the 229 baldpate stomachs, 157, or more than two-thirds, contained pondweeds in some form or other. True pondweeds (*Potamogeton* spp.) were found in 102 stomachs, widgeon grass (*Ruppia maritima*) in 92, eelgrass (*Zostera marina*) in 10, bushy pondweed (*Najas flexilis*) in 9, and horned pondweed (*Zannichellia palustris*) in 8. As in the case of the gadwall, the parts of the pondweeds eaten by the baldpate were almost exclusively leaves and stems, with comparatively few seeds, and birds taken from several different localities evidently had been feeding upon pondweed foliage almost exclusively. One of the plants of this family (*Ruppia maritima*) seems to be well entitled to its common name "widgeon grass," as its foliage is fed upon by the widgeon even more extensively than by the gadwall.

⁵ Sixty-four of these were examined by W. L. McAtee.

Several "widgeons" shot on the shores of Long Island Slough, southwestern Washington, had eaten considerable quantities of the leaves and rootstocks of eelgrass (*Zostera marina*), a few of the stomachs containing no other food.

GRASSES (GRAMINEAE), 13.9 PER CENT.

The principal grasses taken were switchgrass (*Panicum* spp.), by 11 widgeons, wild rice (*Zizania palustris*), by 5, and saltgrass (*Distichlis spicata*), by 5; rangegrass (*Panicum obtusum*), a little barley (*Hordeum pusillum*), and cultivated rice (*Oryza sativa*) were eaten by one each; and in 16 stomachs were grasses which were not identified. Six full stomachs collected in south central Louisiana in March contained practically nothing besides the remains of tender young shoots of switchgrass. Several from other localities were filled with grass fibers and root stocks, and some contained grass seeds. One from Oregon held more than 1,200 seeds of switchgrass in addition to about 2,800 seeds of another grass which was not determined. The only cultivated grain found was a small quantity of rice taken from a stomach collected in Louisiana in January, when the grain could hardly have been anything but waste. The widgeon has been accused of doing considerable damage to fields of growing grain in spring, but such complaints are not borne out by the present investigation. It is very probable that flocks of the ducks do some little harm in this way, but such depredations are the exception rather than the rule.

ALGAE, 7.71 PER CENT.

Algae, consisting chiefly of musk grass, were found in the stomachs of 25 baldpates. More than two-thirds of this food was taken during the months of April and September, by ducks shot in Wisconsin, Michigan, and Minnesota, probably in migration.

SEDGES (CYPERACEAE), 7.41 PER CENT.

The sedges do not play so important a part in the food of the baldpate as with the gadwall and several other ducks, probably because the seeds are the only parts usually eaten, and this duck evidently cares little for seeds. The sedges eaten by the baldpate were: Three-square (*Scirpus americanus*), by 37; prairie bulrush (*S. paludosus*), 12; river bulrush (*S. fluviatilis*), 5; unidentified bulrushes (*Scirpus* spp.), 24; spike rush (*Eleocharis* sp.), 19; chufa (*Cyperus* sp.), 5; saw grass (*Cladium effusum* and *C. mariscoides*), 6; sedges of the genus *Carex*, 12; *Fimbristylis*, 4; and unidentified sedges, by 20. One duck shot in Chihuahua, Mexico, had swallowed no less than 64,000 seeds of spike rush. As a rule the baldpate does not take sedge seeds freely where pondweeds and other aquatic plants with tender foliage are available.

FROGBIT FAMILY (HYDROCHARITACEAE), 5.75 PER CENT.

The plants of the frogbit family eaten by the baldpate consisted of wild celery (*Vallisneria spiralis*), which was found in 12 stomachs, and waterweed (*Philotria canadensis*), in 1. Wild celery is a favorite food of the canvas-back, redhead, and other deep-water ducks, but as a rule it is not often found in the stomachs of ducks which do not dive. However, the stomachs of baldpates from several different localities were filled with wild celery leaves. This is very probably due to a peculiar habit which the baldpate has of following the diving ducks and feeding upon the leaves which they bring to the surface. This habit was noted by Wilson and Bonaparte⁶ as early as 1831, and has been widely quoted by various writers since then. According to these early ornithologists, "The widgeon is the constant attendant of the celebrated canvass-back duck, so abundant in various parts of the Chesapeake Bay, by the aid of whose labour he has ingenuity enough to contrive to make a good subsistence. The widgeon is extremely fond of the tender roots of that particular species of aquatic plant on which the canvass-back feeds, and for which that duck is in the constant habit of diving. The widgeon, who never dives, watches the moment of the canvass-back's rising; and, before he has his eyes well opened, snatches the delicious morsel from his mouth and makes off." It is probable that these observations are not entirely accurate, as the canvas-back is known to feed chiefly upon the rootstocks of the plant; the baldpate merely avails itself of the leaves thus cut off, brought to the surface, and discarded by the canvas-back.

WATER MILFOILS (HALORAGIDACEAE), 3.48 PER CENT.

Water milfoil (*Myriophyllum* sp.) had been eaten by 24 of the baldpates, and bottle brush (*Hippuris vulgaris*) by 18. Many species of ducks feed upon the seeds of these plants in small numbers, but the baldpate so far as known is the only duck which shows any particular fondness for their foliage. Several stomachs were found to contain the seeds also, and in a very few instances they predominated over the foliage, but the bulk of the food derived from this family of plants consisted of the tender leaves and stems. A series of baldpates from Klamath Falls, Oreg., especially, had partaken of the foliage of *Myriophyllum* in considerable quantities.

DUCKWEEDS (LEMNACEAE), 2.2 PER. CENT.

Like the gadwall, the baldpate shows less partiality toward the duckweeds than do some other ducks. The stomachs of three individuals, one each from Wisconsin, Utah, and Oregon, were

⁶ Wilson, Alexander, and Charles Lucian Bonaparte, Amer. Ornith., III, p. 198, 1831.

nearly filled with the small individual plants, or thalli, of a duckweed (*Lemna* sp.). These plants are very abundant in many of the localities from which the baldpates were taken, but for some reason other foods seemed to appeal to them more strongly.

SMARTWEEDS (POLYGONACEAE), 1.47 PER CENT.

The seeds of water smartweed (*Polygonum amphibium*) were present in 11 baldpate gizzards, those of dock-leaved smartweed (*P. lapathifolium*) in six. Others identified were knotweed (*P. aviculare*), water pepper (*P. hydropiper*), and lady's-thumb (*P. persicaria*), each in two, and mild water pepper (*P. hydropiperoides*) and black bindweed (*P. convolvulus*), each in one. The fact that the seeds of smartweeds are the only edible parts of these plants probably is the reason that they form so small an item of the baldpate's diet.

ARROW-GRASS FAMILY (JUNCAGINACEAE), 0.36 PER CENT.

The arrow-grass family was represented in two baldpate stomachs from the State of Washington; both were nearly full of the seeds of arrow-grass (*Triglochin maritima*). These plants are quite closely related to the pondweeds, but, unlike the pondweeds, their seeds are the only parts eaten by birds.

WATERLILY FAMILY (NYPHAEACEAE), 0.26 PER CENT; AND HORNWORT FAMILY (CERATOPHYLLACEAE), 0.24 PER CENT.

One stomach from Oregon was nearly filled with 50 of the large seeds of spatterdock (*Nymphaea* sp.) and fragments of many more. Two others contained seeds of watershield (*Brasenia schreberi*), and one the seeds of another waterlily (*Castalia* sp.).

As already stated, the baldpate seems to lack the gadwall's taste for the foliage of coontail (*Ceratophyllum demersum*). Only one bird (taken in Oregon in December) had its stomach full of this plant, and two others had taken a few of the seeds.

MISCELLANEOUS VEGETABLE FOOD, 7.63 PER CENT.

The stomach of one baldpate from lower Chesapeake Bay contained the remains of about 400 seeds of beggar-ticks, or "pitchforks" (*Bidens* sp.). In another from Texas were over 500 seeds of a wild heliotrope (*Heliotropium indicum*), which are often taken by ducks in much smaller numbers; in this instance they furnished 80 per cent of the contents. A stomach from Virginia was filled with the remains of a great many small tubers of arrowhead (*Sagittaria* sp.); one from Massachusetts contained quantities of the leaves of pipewort (*Eriocaulon* sp.); and one from Utah was from a duck which had made a meal of the foliage and seeds of picklegrass (*Salicornia ambigua*). Among other items found in small quantities were bits of the scales from cones of cypress (*Taxodium distichum*), seeds of bur

reed (*Sparganium* sp.), myrtle (*Myrica* sp.), saltbush (*Atriplex* sp.), purslane (*Portulaca* sp.), crowfoots (*Ranunculus* spp.), brambles (*Rubus* spp.), clovers (*Melilotus* sp. and *Medicago denticulata*), spurge (*Croton* sp.), sumac (*Rhus* sp.), holly (*Ilex* sp.), water hemlock (*Cicuta* sp.), and many others.

ANIMAL FOOD.

Animal food amounted to 6.77 per cent of the contents of the 229 baldpate stomachs included in the computation. Even this figure is probably unduly large, because the greater part of the animal matter consisted of snails found in the gizzards of a series of ducks from southern Oregon, the only lot of birds found feeding almost exclusively upon such food. More than nine-tenths of the animal food (6.25 per cent of the total) consisted of mollusks, the remainder being made up of insects (0.42 per cent) and miscellaneous matter (0.1 per cent).

MOLLUSKS (MOLLUSCA), 6.25 PER CENT.

Fragments of small bivalves were found in 6 stomachs, and snails (univalves) in 29. As already stated, the greater part of the mollusks were from a number of Oregon ducks, taken along the shores of the Klamath River. Many of them had gorged themselves upon snails, and these constituted practically 100 per cent of the contents of 13 out of the 17 stomachs in the series, of which 7 contained nothing else. Two other baldpates, one from Lake Michigan near Chicago, and the other from Lake Manitoba, Canada, had fed largely upon mollusks.

INSECTS (INSECTA), 0.42 PER CENT.

Insects which amounted to only 0.42 per cent of the food of baldpates included in our investigation probably are eaten to a greater extent during the summer months, especially by the ducklings. No ducklings of this species were available, but there can be little doubt that, like the young of the gadwall, they feed largely upon the adults and larvae of aquatic insects.

More than two-thirds of the insects eaten by the baldpate (0.29 per cent of the whole) were beetles. These included water scavenger beetles (Hydrophilidae), found in 8 stomachs; predacious diving beetles (Dytiscidae), in 2; leaf chafers (Scarabaeidae), in 2; leaf beetles (Chrysomelidae), in 3; weevils (Rhynchophora), in 2; Dermestidae, in 2; and unidentified fragments of beetles, in 16. One gizzard contained about 85 individuals of a species of rove beetle (Staphylinidae), a small, elongated, soft-bodied insect, which is usually very common about decaying animal matter.

Flies and their larvae and pupae furnished 0.09 per cent of the food. Twelve baldpates had eaten midges (Chironomidae); 9, ephydrid flies (Ephydriidae); 3, craneflies (Tipulidae); 1, flies of the family

Muscidae; and 1 contained fly remains which were not identified. The larvae of midges are found in immense numbers in stagnant water in many localities, and are often an important food item for water birds.

The remaining insects, amounting to only 0.04 per cent, consisted of a few caddisfly larvae (Phryganoidea), bugs, chiefly water boatmen (Corixidae), a dragonfly nymph, remains of small crickets (*Nemobius* sp.), a small aquatic caterpillar, a few small ants, and unidentified eggs, larvae, and adults of other forms.

MISCELLANEOUS ANIMAL FOOD, 0.1 PER CENT.

Crustaceans furnished less than 1 per cent of the food of the baldpate. They consisted of sand fleas (Amphipoda), bivalved crustaceans (Ostracoda), and a few unidentified forms. One stomach from St. Paul Island, Alaska, was half full of the remains of sand fleas, and contained nothing else. These, together with bits of hydroids, a few spiders and water mites, and the teeth and scales of small fish, made up the remainder of the animal food.

EUROPEAN WIDGEON.

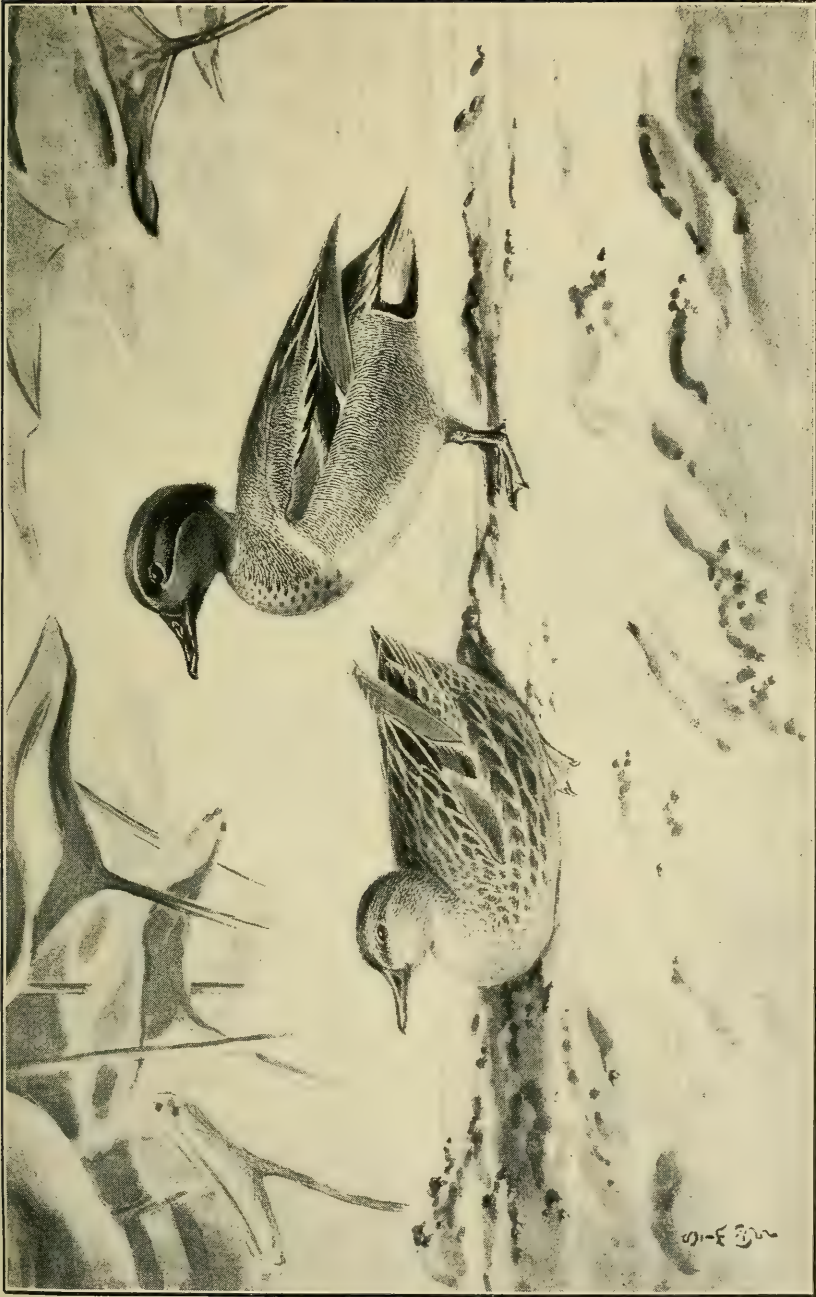
(*Mareca penelope*.)

The European, or red-headed, widgeon is an Old World species but has been noted occasionally at a number of points on the Atlantic coast of North America, and in the North Central and Lake States. There are also several scattered records of its occurrence on the Pacific coast. In appearance the male European widgeon is similar to the baldpate except that the crown is creamy buff instead of white and the remainder of the head and upper part of the neck are reddish brown, with a black area on the chin and throat.

FOOD HABITS.

Not a great deal is known of its food habits in the United States. Sanford,⁷ discussing it, says that, "unlike the American baldpate," it is frequently seen on salt water, feeding almost entirely on the short grass growing on the bottom. However, the baldpate also is known to feed commonly in salt water. Only five stomachs of the European widgeon were available for examination. Two of these were from Back Bay, southeastern Virginia; one contained foliage of widgeon grass (*Ruppia maritima*) and eelgrass (*Zostera marina*); the other, only widgeon grass. The third was from the flats of the Susquehanna River near its mouth in northeastern Maryland and contained rootstocks of pondweeds (*Potamogeton* sp.), bits of stems and a few seeds of dodder (*Cuscuta* sp.), and a few seeds of bur-reed (*Sparganium* sp.). The fourth stomach, from the vicin-

⁷ Sanford, L. C., L. B. Bishop, and T. S. Van Dyke, The Waterfowl Family, p. 91, 1903.



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GREEN-WINGED TEAL (NETTION CAROLINENSE).
Male on right; female on left.

ity of Currituck Sound, North Carolina, contained leaves of eelgrass. The fifth, from Ipswich, Mass., contained only seeds of salt-marsh bulrush (*Scirpus robustus*). Thus it will be seen that in all probability the food of the European widgeon does not differ materially from that of its American cousin, the baldpate.

GREEN-WINGED TEAL.

(*Nettion carolinense*).

PLATE III.

The green-winged teal, variously known to sportsmen as green-wing, mud teal, winter teal, or red-headed teal, has a very wide distribution, being found in the breeding season from New York, northern Pennsylvania, Michigan, Nebraska, Colorado, and New Mexico northward to the edge of the Barren Grounds; from near Fort Churchill, Hudson Bay, to Kotzebue Sound; and nearly to Point Barrow, Alaska. The main breeding grounds are in west central Canada from Manitoba to Lake Athabaska, and the bird breeds only rarely in the United States east of the Rocky Mountains. It winters commonly in Mexico and the Bahamas, and rarely in Cuba, Jamaica, and Honduras; occasionally south to Tobago. It is also very common in winter in the Southern States, and many individuals remain throughout the winter as far north as they can find open water. It is one of the early ducks to migrate in spring, usually reaching the latitude of New York City during the first week in April, and arriving at the northern limits of its breeding range by about the first of May.

The adult male green-winged teal can best be distinguished by its dark brown head with a patch of metallic green on each side, including the eye, and extending into a crest at the back of the head. It has also a white crescent in front of the wing and a metallic green speculum or wing patch. This wing patch is not so distinct on the female and young. Any of the teals can be distinguished from most of the other ducks by their small size, the green-wing measuring $12\frac{1}{4}$ to 15 inches in length, the blue-wing $14\frac{1}{2}$ to 16 inches, and the cinnamon teal about 17 inches.

FOOD HABITS.

The green-winged teal feeds largely upon the seeds of pondweeds, bulrushes, and other aquatic plants, although it takes also a smaller proportion of such animal food as insects, small crustaceans, and snails. When much disturbed during the daytime, the flocks feed largely at night. The flesh of the green-wing is very palatable, being considered among the best of American ducks, although it is said soon to become less palatable when the birds have been driven to the seashore and feed upon snails and salt-water crustaceans. On

account of the fact that the birds have little suspicion of man and fly in compact flocks, affording opportunities for pot shots, the green-winged teal has been greatly reduced in numbers. It is one of our most desirable game birds and should be carefully guarded against further depletion.

VEGETABLE FOOD.

Of the contents of 653⁸ green-winged teal stomachs examined, more than nine-tenths (90.67 per cent) consisted of vegetable matter. By far the largest item of food contributed by any one family of plants came from the sedges, and this amounted to nearly two-fifths (38.82 per cent) of the total food. Next to the sedges, pondweeds are the favorite food supply, contributing 11.52 per cent, while grasses follow closely with 11, then smartweeds 5.25, algae 4.63, duckweeds 1.9, water milfoils 1.11, arrow-grass 0.91, and bur reed 0.85 per cent. The remaining 14.68 per cent is made up of a great number of smaller items.

SEDGES (CYPERACEAE), 38.82 PER CENT.

The sedges form a very constant item of food for the green-winged teal, being found in some form in 530 of 653 stomachs and forming the sole content of 51. Usually the seeds are taken, but practically all parts of the plants are eaten when young and tender. Seeds of bulrushes (*Scirpus* spp.) form the largest item among the sedges, being found in the greatest number of stomachs and represented by several species. Unidentified bulrush seeds were found in 205 stomachs. The most commonly identified species was three-square (*Scirpus americanus*) from 121 stomachs. Seeds of prairie bulrush (*Scirpus paludosus*) were found in 46 stomachs, those of salt-marsh bulrush (*Scirpus robustus*) in 40, *Scirpus cubensis* in 13, and river bulrush (*Scirpus fluviatilis*) in 5. Other genera of sedges represented were *Fimbristylis*, found in 90 stomachs, *Carex* in 72, *Cyperus* 48, spike rush (*Eleocharis*) 45, beaked rushes (*Rhynchospora*) 5, saw grass (*Cladium*) 91, and unidentified sedge seeds in 44. No fewer than 30,000 seeds of a *Cyperus* were found in one stomach and 25,000 in another, while *Eleocharis* and *Fimbristylis* seeds also occasionally reached as high as 1,000 per stomach.

PONDWEEDS (NAIADACEAE), 11.52 PER CENT.

The pondweed group includes the true pondweeds (*Potamogeton* spp.), ditch or widgeon grass (*Ruppia maritima*), horned pondweed (*Zannichellia palustris*), eelgrass (*Zostera marina*), and bushy pondweed (*Najas* spp.), all of which were found in stomachs of the green-winged teal, and seem to form a very important element of their diet. In most cases the seeds alone are taken, but the ducks

⁸ Two hundred and sixteen of these were examined by W. L. McAtee.

often eat also the stems, leaves, buds, and tubers of some species of *Potamogeton*, leaves and rootstocks of ditchgrass, and parts of the foliage of bushy pondweed, eelgrass, and horned-pondweed. *Potamogeton* (usually seeds) was found in 250 stomachs. In a few instances the species were identified, the most common being sago pondweed (*Potamogeton pectinatus*); but usually it was useless to attempt to identify species by the seeds, as they are so much alike as to be indistinguishable in the worn condition in which they are found in the stomachs. Seeds of this genus, however, even when present in small fragments, are easily distinguished from other seeds by the peculiar curved shape of the cavity which contains the embryo. The seeds of widgeon grass were found in 108 gizzards, and fragments of the leaves were identified from three. Seeds of eelgrass were present in 3 stomachs, bushy pondweed in 27, and horned pondweed in 10. One of the latter stomachs contained more than 1,300 seeds.

GRASSES (GRAMINEAE), 11 PER CENT.

Eighteen species of grass seeds were identified from the birds examined, and unidentified grass seeds were taken from 19 stomachs. Those of the genus *Panicum* were most commonly eaten, being found in 59 gizzards, often constituting a large proportion of the contents, and reaching as high as two or three thousand in number. Another favorite seed was that of barnyard grass, or wild millet (*Echinochloa crus-galli*), which was found in 14 stomachs, and usually formed the bulk of the food whenever it occurred. One duck taken in Louisiana in January had eaten 6,000 seeds of jungle rice (*Echinochloa colona*), both the stomach and gullet being crammed full. Other grass seeds eaten by this teal were wild rice (*Zizania palustris*), taken by 18 birds; cut-grass (*Zizaniopsis miliacea*), by 8; foxtail grasses (*Chaetochloa glauca* and other species), 9; and *Monanthochloë littoralis*, 16. A few kernels of corn had been taken by one bird, and rice by 21. However, all these ducks were collected during the winter months, and the rice and corn were undoubtedly waste grain.

SMARTWEEDS (POLYGONACEAE), 5.25 PER CENT.

Next in order of importance in the food of the green-winged teal come the smartweeds, which form one of the principal items of food of a great many birds. Thirteen species of smartweed were identified, the most important being water smartweed (*Polygonum amphibium*), found in 35 stomachs; dock-leaved smartweed (*P. lapathifolium*), in 29; Opelousas smartweed (*P. opelousanum*), 14; water pepper (*P. hydropiper*), 12; and mild water pepper (*P. hydropiperoides*), 10. The other smartweeds were found in only a few stomachs each, and those taken from 22 other birds were not identified. One

duck had eaten 1,630 seeds of knotgrass (*Polygonum aviculare*). Seeds of dock (*Rumex* spp.), another plant of the smartweed family, had been taken by 5 birds.

ALGAE, 4.63 PER CENT.

Musk grass (*Chara* sp.) forms the bulk of the algae taken by the green-winged teal, being found in 89 of the 96 stomachs which contained algae. All parts of the plant are eaten freely, but the ducks seem to be especially fond of the oögonia, very small spherical or egg-shaped objects which form part of the reproductive apparatus and are attached to the whorled leaves. They are usually coated with lime and are rather hard, and consequently often remain in the stomach after all other parts of the plant are digested. Stomachs were found containing thousands of them, and occasionally they constituted the total contents. Musk grasses, of which there are many species, have a very wide distribution, and have been found in duck stomachs from practically all parts of North America.

DUCKWEEDS (LEMNACEAE), 1.9 PER CENT.

The duckweeds, the simplest and smallest of flowering plants, form a rather important element in the food of nearly all ducks which live on plant matter. These plants, at least in the typical genera, consist of merely a frond or leaf floating freely upon the water, with one or more small roots dangling below. The fronds are fleshy and tender, and are scooped up greedily by the ducks. They had been taken by 44 of the 653 green-winged teal examined, and averaged 1.9 per cent of the total food.

WATER MILFOIL FAMILY (HALORAGIDACEAE), 1.11 PER CENT.

The water milfoil family is represented in North America by three genera: Water milfoil (*Myriophyllum*), mermaid-weed (*Proserpinaca*), and bottle brush (*Hippuris*). The seeds of all three of these were present in the series of gizzards examined. Water milfoil seeds had been eaten by 58 birds, those of bottle brush by 16, and those of mermaid-weed by only one.

ANIMAL FOOD.

Insects formed 4.57 per cent of the total food of the green-winged teal, the remainder of the animal food consisting of mollusks, 3.59 per cent; crustaceans, 0.92; and miscellaneous, 0.25; the total amounting to 9.33 per cent.

INSECTS (INSECTA), 4.57 PER CENT.

The largest item of insect food eaten by these ducks was flies (Diptera), which constituted 2.07 per cent of the total. Nearly all of these were in the form of larvae or pupae, the adult flies seldom being caught. Probably those found had been taken from the surface of the water, as it does not seem likely that a duck would be

adept at fly-catching. The larvae of midges (Chironomidae) were found in 61 stomachs, sometimes in very large numbers, and formed the bulk of the dipterous food taken. They are abundant in shallow, standing water and slow streams almost everywhere, feeding upon decayed vegetable matter, and evidently are eagerly sought by the ducks. The larvae and pupae of craneflies (Tipulidae), soldierflies (Stratiomyidae), and Ephyridae were also commonly taken.

Although beetles (Coleoptera) formed only 0.65 per cent of the total food, they were represented by a larger number of families and genera than the flies. Those most commonly taken were predacious diving beetles (Dytiscidae), water scavenger beetles (Hydrophilidae), crawling water beetles (Haliplidae), snout beetles and other weevils (Rhynchophora), and ground beetles (Carabidae).

Next in order of importance in the insect food of this teal come the bugs (Hemiptera), with 0.54 per cent, including both the true bugs (Heteroptera) and the cicadas, leafhoppers, etc. (Homoptera). Of the true bugs, water boatmen (Corixidae) were found in 32 stomachs, sometimes in very large numbers; back swimmers (Notonectidae) in 4 stomachs; water striders (Gerridae) in 4; and unidentified bugs in 6. The Homoptera were represented by a single jassid, or leafhopper.

Caddisflies (Phryganoidea) furnished 0.31 per cent of the total food of the birds examined. These were taken in the form of the larvae, or caddis worms, which abound in creeks and ponds, or anywhere in shallow water containing the vegetation upon which the fly larvae feed. They live within silk cases or hollow cylinders made by themselves and covered with a variety of materials, such as grains of sand, bits of leaves or rushes, or pieces of mollusk shell. These cases are open at each end, and the larva pulls itself along by means of three pairs of legs which, with the head, can be protruded from one end. Caddis larvae or cases were found in 46 stomachs, never in very large numbers.

The remaining insect food (1 per cent) was made up of damselflies (Zygoptera), dragonflies (Anisoptera), stoneflies (Plecoptera), bird lice (Mallophaga), grasshoppers (Orthoptera), ant-lions (Neuroptera), moths and butterflies (Lepidoptera), ants, bees, and wasps (Hymenoptera), and a number of miscellaneous unidentified insects and their eggs, pupae, and larvae. Probably the largest single item among these miscellaneous orders of insects was the nymphs of damselflies and dragonflies, identified from 23 stomachs.

MOLLUSKS (MOLLUSCA), 3.59 PER CENT.

Next to insects, mollusks furnished the largest item of animal food for this teal, 3.59 per cent of the total. They were usually found broken, although whole snails were sometimes present. Empty

shells or bits of shell probably are often taken by ducks in lieu of gravel to help grind the food, but there is no doubt that the mollusks themselves, and especially snails, are relished by the birds and form an important element in their food. Three genera of snails were identified: *Physa*, *Neritina*, and *Planorbis*. Unidentified snails were taken from 44 stomachs, and bivalves from only 3. Broken mollusk shells, unclassified, were found in 90 gizzards.

CRUSTACEANS (CRUSTACEA), 0.92 PER CENT.

Small crustaceans, which are abundant in numbers and variety in nearly all streams and bodies of water, whether salt or fresh, are sought by nearly all ducks. They furnished 0.92 per cent of the total food of the green-winged teal, or approximately one-tenth of the animal food. Chief among these were the ostracods, small bivalved crustaceans which might easily be mistaken for minute mollusks. Small shrimplike crustaceans known as amphipods were taken in some numbers, and in one stomach the claws of an unidentified crab were found.

MISCELLANEOUS ANIMAL FOOD, 0.25 PER CENT.

A few spiders and mites (class Arachnida), centipeds (Myriapoda), fish scales, minute aquatic animalculae, and other insignificant items form the remainder of the green-winged teal's animal food.

BLUE-WINGED TEAL.

(*Querquedula discors*.)

PLATE IV.

The blue-winged teal, blue-wing, or summer teal is slightly more restricted in its distribution than the green-wing. Although it has been recorded as breeding in Rhode Island, Maine, New Brunswick, Nova Scotia, Newfoundland, Quebec, Ontario, and New York, and as far south as northern Ohio, southern Indiana, southern Colorado, New Mexico, Texas, Utah, northern Nevada, and central Oregon, it is not common east of the Allegheny Mountains nor on the Pacific slope. Its principal summer home is in the interior of North America between the Rocky Mountains and the Great Lakes, from northern Illinois and Nebraska north to Saskatchewan. Its principal range extends north to British Columbia, and it occurs also rarely north to Alaska, Alberta, and about Great Slave Lake. In winter, blue-winged teals are found throughout northern South America south to Brazil, Ecuador, Peru, and Chile; they occur abundantly in Central America, Mexico, and the West Indies; and in the United States they are found near the Gulf, and as far north as North Carolina, and (sparingly) southern Indiana and southern Illinois. Unlike the green-winged teal, this is one of the least hardy of our ducks, migrating late in spring



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BLUE-WINGED TEAL (*QUERQUEDULA DISCORS*).

Male on left; female on right.

and early in fall. It usually arrives in central Iowa during the last week in March, and at Aweme, Manitoba, about a month later. In the fall migration it reappears throughout the northern half of the United States during the month of August and reaches the Gulf of Mexico about the middle of September. In habits it is very similar to the green-winged teal, and like that bird its numbers have been greatly diminished in recent years on account of its slight fear of man and the consequent ease with which it may be shot by even inexperienced sportsmen. It is especially rare in most of the States east of the Alleghenies, and great care should be taken in some localities to see that it is not entirely wiped out.

In general appearance the blue-winged teal is similar to the green-wing, having also a green speculum, which, however, is supplemented by a light-blue shoulder patch, separated from the green by a narrow white line. The adult male also lacks the white mark before the wing, which is present in the green-winged teal, but has a large white crescent on each side of the face in front of the eye.

FOOD HABITS.

To determine the food habits of the blue-winged teal, 319⁹ stomachs were examined, collected from 29 States and 4 Canadian Provinces during a period of 31 years, and in every month but January. As might be expected, the greatest numbers were collected in the fall, during the months of September, October, and November, making the average percentages of various kinds of foods for those months more accurate than for the remainder of the year. Rather large series were collected in Wisconsin (58), Florida (46), Maine (40), and North Dakota (36); the remaining stomachs were fairly evenly distributed. The character of the contents of the stomachs from the States furnishing the largest numbers was not such as to influence unduly the final averages.

VEGETABLE FOOD.

About seven-tenths (70.53 per cent) of the blue-winged teal's food consists of vegetable matter. Of this about three-fourths is included in four families of plants. Sedges (Cyperaceae), with 18.79 per cent; pondweeds (Naiadaceae), 12.6; grasses (Gramineae), 12.26; and the smartweeds (Polygonaceae), 8.22. The remainder of the plant food is made up of algae, 2.95 per cent; waterlilies (Nymphaeaceae), 1.37; rice and corn, 0.98; water milfoils (Haloragidaceae), 0.71; bur reeds (Sparganiaceae), 0.38; madder family (Rubiaceae), 0.35; and miscellaneous, 11.92 per cent.

⁹ Ninety of these were examined by W. L. McAtee.

SEDGES (CYPERACEAE), 18.79 PER CENT.

The sedges are grasslike or rushlike plants which grow in marshes or on the borders of ponds and streams. Ducks are especially fond of their seeds, which usually are small and hard and have a starchy interior. The family of sedges is a very large one, comprising about 3,200 species, widely distributed. The seeds most often found in duck stomachs are those of the bulrushes (*Scirpus* spp.), and the case of the blue-winged teal is no exception to this rule. Unidentified bulrush seeds were found in 184 stomachs, those of river bulrush (*S. fluviatilis*) in 18, three-square (*S. americanus*) in 10, prairie bulrush (*S. paludosus*) in 7, and great bulrush (*S. validus*) and salt-marsh bulrush (*S. robustus*) in 2 each. Other sedges taken were those of the genus *Carex*, found in 59 stomachs; saw grass (*Cladium efusum* and *C. mariscoides*), in 55; chufa (*Cyperus* spp.), in 45; spike rush (*Eleocharis* spp.), in 33; beaked rush (*Rhynchospora* sp.), in 2; and sedges of the genera *Fimbristylis*, in 40; and *Dulichium*, in 2. Unidentified sedge seeds or bits of the plants were taken by 27 birds.

PONDWEEDS (NAIADACEAE) 12.6 PER CENT.

In 33 of the stomachs examined the seeds or other parts of pondweeds formed from 95 to 100 per cent of the total food contents. The true pondweeds (*Potamogeton* spp.) had been taken by 151 birds, widgeon grass (*Ruppia maritima*) by 87, bushy pondweed (*Najas flexilis* and *N. marina*) by 18, eelgrass (*Zostera marina*) by 3, and horned pondweed (*Zannichellia palustris*) by 2. One stomach held over 700 of the hard black seeds of widgeon grass. Most ducks feed upon all parts of pondweed plants, and the blue-winged teal seems to pay much attention to the leaves and stems as well as the seeds.

GRASSES (GRAMINEAE), 12.26 PER CENT.

Of the 319 blue-winged teals examined, only 13 had eaten cultivated grain. One of these, obtained in Kansas in April, had its gizzard filled with 19 kernels of corn and fragments of more, but corn taken at that time of year could hardly have been anything but waste. The other 12 birds had eaten rice, and as all were collected in Florida in November, this, too, was undoubtedly waste grain. Of the wild grasses the favorites were wild rice (*Zizania palustris*), taken by 22 birds; switchgrass (*Panicum* sp.), by 18; the foxtails (*Chaetochloa glauca*, *C. viridis*, and others), by 14; rice cut-grass (*Homalocenchrus oryzoides*), by 9; and *Monanthochloë littoralis*, by 13. Other species less often taken were meadow grass (*Puccinellia nuttalliana*), barnyard grass (*Echinochloa crus-galli*), cut-grass (*Zizaniopsis miliacea*), rushgrass (*Sporobolus* sp.), and salt-marsh grass (*Spartina* sp.).

SMARTWEEDS (POLYGONACEAE), 8.22 PER CENT.

Two of the blue-winged teals had eaten seeds of dock (*Rumex* sp.). All other seeds of this family taken were of the true smartweeds (*Polygonum* spp.). These were represented by 9 species, and 16 stomachs contained unidentified smartweed seeds. Mild water pepper (*Polygonum hydropiperoides*), which was found in 31 stomachs; water smartweed (*P. amphibium*), in 27; and dock-leaved smartweed (*P. lapathifolium*), in 26, were the kinds most often found. Other species taken were prickly smartweed (*P. sagittatum*), lady's-thumb (*P. persicaria*), water pepper (*P. hydropiper*), Opelousas smartweed (*P. opelousanum*), Pennsylvania smartweed (*P. pennsylvanicum*), and dense-flowered smartweed (*P. portoricense*).

ALGAE, 2.95 PER CENT.

The greater part of the seaweeds taken consisted of musk grass (*Chara* spp.). Several stomachs collected in Wisconsin, North Dakota, and Florida were nearly full of this alga, chiefly the oogonia, or reproductive cells. Altogether, musk grass was found in 31 stomachs, and unidentified marine algae, or seaweeds, in 4.

WATERLILIES (NYMPHAEACEAE), 1.37 PER CENT.

Waterlily seeds had been taken by 27 of these teals. Fourteen had eaten seeds of white waterlilies (*Castalia* sp.), and the other 13 had eaten those of the small purple waterlily known as water shield (*Brasenia schreberi*). Most of the white waterlily seeds were found in the stomachs of a series of ducks collected in Florida. One of these, together with the bird's gullet, which was also full, contained 1,600 seeds and fragments of many more.

WATER MILFOILS (HALORAGIDACEAE), 0.71 PER CENT.

The plants of the family Haloragidaceae have a very wide geographic distribution. They are chiefly aquatic, and have hard, nutlike seeds which persist for some time in bird stomachs. The three North American genera were represented in the stomachs examined, bottle brush (*Hippuris vulgaris*) in 8, mermaid weed (*Proserpinaca* sp.) in 5, and water milfoil (*Myriophyllum* sp.) in 44.

BUR REEDS (SPARGANIACEAE), 0.38 PER CENT.

The seeds of bur reed (*Sparganium* sp.) had been eaten by 39 of the blue-winged teals examined, but usually were found in small numbers.

MADDER FAMILY (RUBIACEAE), 0.35 PER CENT.

The madder family was rather sparingly represented by seeds of buttonbush (*Cephalanthus occidentalis*), found in 5 stomachs; bed-straw, or cleavers (*Galium* sp.), in 10; and rough buttonweed (*Diodia teres*) in 1.

MISCELLANEOUS VEGETABLE FOOD, 11.95 PER CENT.

A large number of minor items of vegetable food were classified as miscellaneous. Probably the largest of these consisted of plants of the duckweed family (Lemnaceae). Although found in only 14 stomachs, they constituted nearly 100 per cent of the contents of several. Each of three stomachs collected in Iowa in August contained more than a thousand of the small plants of a duckweed (*Lemna* sp.). Twenty-eight other families of plants were represented, the most important being the aster family (Compositae), the water plantain family (Alismaceae), the parsley family (Umbelliferae), crowfoot family (Ranunculaceae), borage family (Boraginaceae), myrtle family (Myricaceae), rose family (Rosaceae), hornwort family (Ceratophyllaceae), and the vervain family (Verbenaceae).

ANIMAL FOOD.

Animal matter constitutes 29.47 per cent of the total food of the blue-winged teal, which is more than three times the percentage of animal food eaten by the green-wing. Over half of this (16.82 per cent) is mollusks, the remainder being made up of insects, 10.41 per cent; crustaceans, 1.93, and miscellaneous, 0.31 per cent.

MOLLUSKS (MOLLUSCA), 16.82 PER CENT.

The greater part of the shellfish found in the stomachs examined probably consisted of snails, although small bivalves also had been commonly taken, and in a majority of cases the shells had been so thoroughly crushed by the powerful gizzards of the ducks as to make it impracticable to distinguish between the fragments of bivalves and univalves. However, 15 species of the latter were identified, and 2 of the former. Unidentified univalve shells were found in 31 stomachs and unidentified bivalves in 2, while fragments of mollusk shells taken from 106 stomachs were not classified. The full stomach of a duck collected in an Iowa swamp in August, 1907, contained thousands of snail eggs, amounting to 54 per cent of its contents.

INSECTS (INSECTA), 10.41 PER CENT.

The items of insect food of the blue-winged teal, in the order of their importance, are caddis larvae (together with their cases), beetles and their larvae, dragonflies and damselflies (chiefly in the nymph stage), bugs, flies (chiefly larvae), and a small percentage of miscellaneous insects.

The larvae of caddisflies (Phryganoidea) or their cases were found in 37 stomachs, and amounted to 4.5 per cent of the total food. The greater part of these were found in a series of stomachs collected in Florida, some of which were over half filled with the fragments of caddis cases.

Beetles (Coleoptera) amounted to 2.62 per cent of the food of the blue-winged teal, or less than one-tenth of the total animal matter eaten. Ten species of predacious diving beetles (Dytiscidae) were noted, 7 of ground beetles (Carabidae), 5 of water scavenger beetles (Hydrophilidae), 4 of crawling water beetles (Haliplidae), 3 of leaf chafers (Scarabaeidae), 3 of leaf beetles (Chrysomelidae), 2 each of snout beetles (Curculionidae) and billbugs (Calandrinae), and 1 each of whirligig beetles (Gyrinidae), shining carrion beetles (Histeridae), pill beetles (Byrrhidae), and mud beetles (Heteroceridae); while many individuals of most of these families were found which, on account of their fragmentary condition, could not be further identified. Unclassified beetle remains were found in 50 stomachs.

The nymphs or young of damselflies (Zygoptera) and dragonflies (Anisoptera) live in the water and afford delicate morsels for ducks. Twenty-two of the blue-winged teals had eaten nymphs of dragonflies and two those of damselflies, while three stomachs contained remains of nymphs which were not identified.

Bugs (Heteroptera and Homoptera) constituted 0.86 per cent of the birds' diet. These represented 10 families, besides the remains of a few bugs which were not identified. Water boatmen (Corixidae) had been eaten by 43 birds, creeping water bugs (Naucoridae) by 15, back swimmers (Notonectidae) by 12, water striders (Gerridae) and broad-shouldered water striders (Veliidae) by 2 each, and negro bugs (Corimelaenidae), stink bugs (Pentatomidae), giant water bugs (Belostomatidae), planthoppers (Fulgoridae), and leafhoppers (Jassidae) by 1 each.

Only 0.65 per cent of the blue-winged teal's food consisted of two-winged flies and their larvae and pupae. Six families were represented, and unidentified larvae or pupae were taken from 8 stomachs. The larvae of soldierflies (Stratiomyidae) and midges (Chironomidae) were present in 11 gizzards each, while those of flower flies (Syrphidae) had been eaten by 4 birds, and Anthomyiidae, Ephydriidae, and black flies (Simuliidae) by 1 each.

The miscellaneous insect food consisted of unidentified fragments of insects, a grasshopper or two, 3 small moth cocoons, a few ants, insect eggs, etc.

CRUSTACEANS (CRUSTACEA), 1.93 PER CENT.

Crustaceans furnished 1.93 per cent of the contents of all the blue-winged teal gizzards examined, and consisted of beach fleas, scuds, etc. (Amphipoda), found in 7 stomachs; small bivalved crustaceans (Ostracoda), in 8; and stalk-eyed crustaceans (Decapoda), in 2. The last-mentioned order includes the claw of a crab found in one stomach and a sand shrimp (*Crangonyx gracilis*) in the other. Two North Carolina stomachs collected in March were nearly filled

with beach fleas, or amphipods. Crustaceans which had been taken by 5 other teals were too fragmentary for identification.

MISCELLANEOUS ANIMAL FOOD, 0.31 PER CENT.

The miscellaneous animal food, which amounted to only 0.31 per cent, consisted principally of the remains of a few minnows and other small fishes, a few spiders, and several tiny water mites, or hydrachnids.

CINNAMON TEAL.

Querquedula cyanoptera.

PLATE V.

The cinnamon teal is a western bird, its breeding range in North America extending from eastern Wyoming and western Kansas west to the Pacific coast, and from southern British Columbia and southwestern Alberta south to northern Lower California, northern Mexico, southern New Mexico, and central western Texas. Its distribution is very remarkable in that it not only breeds in the Northern Hemisphere, but also over a large area in South America, the two colonies being separated by a zone about 2,000 miles wide in which the species is practically unknown. The cinnamon teal of North America migrates in winter only a short distance south of its breeding range in Mexico and is found at this season as far north as Brownsville, Tex., central New Mexico, southern Arizona, and Tulare Lake, California. The South American birds migrate slightly northward after nesting, but the breeding seasons of the two colonies are, of course, reversed.

The male cinnamon teal differs from the blue-wing in appearance in having a blackish area on the top of the head, and chestnut or cinnamon brown on the remainder of the head, neck, and underparts, giving it the local name of red-breasted teal.

FOOD HABITS.

Only 41 stomachs of the cinnamon teal were available for examination. These were collected during the eight months from March to October, and from the States of Colorado, Utah, Arizona, Montana, Oregon, and California, the bulk being from Utah and California. Although the number is too small to furnish an accurate estimate of the percentages of various foods taken, nevertheless the results are of value in showing that this species probably does not differ materially in habits from the other two North American teals.

VEGETABLE FOOD.

Like the green-wing and the blue-wing, the cinnamon teal lives mainly upon vegetable food, this comprising about four-fifths (79.86 per cent) of the total contents of the stomachs examined. And like the other teals its two principal and most constant items of food are the



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CINNAMON TEAL (*QUERQUEDULA CYANOPTERA*).
Male on left; female on right.



seeds and other parts of sedges (Cyperaceae) and pondweeds (Naiadaceae). These two families of plants furnished 34.27 and 27.12 per cent, respectively, of the bird's entire diet. The grasses (Gramineae) amounted to 7.75 per cent; smartweeds (Polygonaceae), to 3.22; mallows (Malvaceae), 1.87; goosefoot family (Chenopodiaceae), 0.75; water milfoils (Haloragidaceae), 0.37; and miscellaneous, 4.51.

SEDGES (CYPERACEAE), 34.27 PER CENT.

Twelve birds had eaten seeds of prairie bulrush (*Scirpus paludosus*), 3 those of three-square (*S. americanus*), and the stomachs of 17 contained seeds of unidentified bulrushes. Seeds of spike rush (*Eleocharis* sp.) had been taken by 10, seeds of *Carex* by 5, and unidentified sedges by 7.

PONDWEEDS (NALADACEAE), 27.12 PER CENT.

The pondweeds eaten consisted of seeds of true pondweeds (*Potamogeton* spp.), found in 33 stomachs; widgeon grass (*Ruppia maritima*), in 16; and horned pondweed (*Zannichellia palustris*), in 10. One duck had eaten over 400 large seeds of *Potamogeton*, and another 950 seeds of widgeon grass.

GRASSES (GRAMINEAE), 7.75 PER CENT.

The seeds of *Monanthochloë littoralis* were identified from 5 stomachs. Other grass seeds and bits of grass fiber were found in 3.

SMARTWEEDS (POLYGONACEAE), 3.22 PER CENT.

Seeds of smartweed (*Polygonum lapathifolium*) had been eaten by 3 of the cinnamon teals, those of lady's-thumb (*P. persicaria*) by 1, and unidentified smartweeds by 3. Two birds had taken seeds of dock (*Rumex* sp.).

MALLOW FAMILY (MALVACEAE); GOOSEFOOT FAMILY (CHENOPODIACEAE); AND WATER MILFOIL FAMILY (HALORAGIDACEAE), 2.99 PER CENT.

Two stomachs contained unidentified seeds of the mallow family, amounting to 1.87 per cent of the whole. Another contained fragments of several hundred seeds of a pigweed (*Chenopodium* sp.), furnishing 0.75 per cent. Three birds had eaten seeds of bottle brush (*Hippuris vulgaris*) and 2 those of water milfoil (*Myriophyllum* sp.), together amounting to 0.37 per cent of the total.

MISCELLANEOUS VEGETABLE FOOD, 4.51 PER CENT.

A few seeds each of bur reed (*Sparganium* sp.), amaranth (*Amaranthus* sp.), yellow water-crowfoot (*Ranunculus delphinifolius*), bur clover (*Medicago denticulata*) and other clovers (*Medicago* sp. and *Trifolium* sp.), California sumach (*Rhus laurina*), heliotrope (*Heliotropium indicum*), and cleavers (*Galium* sp.), and traces of musk grass (*Chara* sp.), made up the remainder of the bird's vegetable food.

ANIMAL FOOD.

The 41 cinnamon teals examined had made of animal matter 20.14 per cent of their food. This consisted of insects, 10.19 per cent; mollusks, 8.69 per cent; and a few small miscellaneous items, 1.26 per cent.

INSECTS (INSECTA), 10.19 PER CENT.

Over half the insect food of the series of cinnamon teals (5.4 per cent of the whole) consisted of beetles (Coleoptera). Disregarding several unidentified fragments, only four families were represented, the predacious diving beetles (Dytiscidae), water scavenger beetles (Hydrophilidae), leaf beetles (Chrysomelidae), and snout beetles (Curculionidae).

The bugs (Heteroptera) amounted to 2.97 per cent, and consisted entirely of water boatmen (Corixidae). These are small brown or gray mottled bugs, with oarlike legs well fitted for swimming; they frequent the lakes, ponds, and streams throughout the greater part of North America, and are commonly eaten by many species of water birds. As they are very good swimmers, it must require quick work on the part of the ducks to catch them. They were found in 11 of the 41 stomachs.

Remains of dragonflies (Anisoptera) were found in two gizzards, and a nymph of a dragonfly or a damselfly in another. The dragonflies and damselflies (Zygoptera) together constitute the superorder Odonata, which furnished 0.92 per cent of the food of the cinnamon teal.

The flies (Diptera) taken were mostly larvae, and amounted to 0.62 per cent. Flies of at least four families—the midges (Chironomidae), soldierflies (Stratiomyidae), flower flies (Syrphidae), and brine flies (Ephydriidae)—were included. A few insect eggs, bits of the cases of caddis larvae (Phryganoidea), two small hymenopterous cocoons, and the remains of an ant, together amounting to 0.28 per cent, made up the remainder of the insect food.

MOLLUSKS (MOLLUSCA), 8.69 PER CENT.

Four of the cinnamon teals had fed upon snails and two upon small bivalves, and the stomachs of 15 contained fine fragments which were not classified. Altogether, mollusks amounted to 8.69 per cent of the bird's diet, a proportion considerably greater than that of the green-winged teal, but only about half as great as that of the blue-wing.

MISCELLANEOUS ANIMAL FOOD, 1.26 PER CENT.

The stomach of a young bird collected near Great Salt Lake, Utah, in July, was half filled with fine feathers. These, together with a few water mites (Hydrachnidae), bivalved crustaceans (Ostracoda), and a small quantity of unidentified matter from other stomachs, all of which amounted to 1.26 per cent, made up the remainder of the animal food of the species.

PINTAIL.*(Dafila acuta.)*

PLATE VI.

The pintail breeds abundantly along the northern border of the United States from Lake Superior almost to the Pacific, and northward to the Arctic coast northwest of Hudson Bay and west to Alaska. It is uncommon as a breeder east of a line drawn from the western side of Hudson Bay to the western shore of Lake Michigan, and south of the northern tier of States except on the Great Plains. It breeds also south to northern Illinois, southern Colorado, and southern California, winters as far south as Cuba and Panama, and abundantly in the southern half of the United States. The species breeds also in the northern portions of the Old World and migrates south in winter to northern Africa and southern Asia.

The pintail is easily recognized by its long neck as well as by the long, pointed middle tail feathers from which it derives most of its common names. In addition to "pintail" it is sometimes known locally as "sprig," "sprig-tail," "sharp-tail," and "spike-tail." A cinnamon-brown wing bar, present in both sexes, also is distinctive. The adult male has a very dark brown head, a white stripe on each side of the neck, and the sides and back finely marked with black and white wavy lines.

FOOD HABITS.

In its general habits the pintail quite closely resembles the mallard, although it probably spends less time feeding on dry land remote from the water. It is not particularly adept at diving, but nevertheless obtains much of its food from under the surface and often from the bottom in shallow water, by tipping-up for it. It nests in low meadows or sloughs, frequently some distance from water. The female is very solicitous in the care of her young, attempting to decoy an intruder away from them by playing wounded, or to distract his attention by circling around and quacking loudly. In autumn, pintails usually gather in good-sized flocks either by themselves or with other shallow-water ducks, and are much sought after for their flesh, which is very palatable.

The stomachs of 790 ¹⁰ pintails, collected from practically all parts of North America from Alaska and Hudson Bay to California, Texas, and Florida, were available for this investigation. The largest numbers were taken in the States of Louisiana (172), Washington (139), Texas (110), Utah (91), Florida (44), and North Carolina (42), the remainder being well scattered. Of the total number, data on the contents of 769, representing the months from September to March, inclusive, were used in computing averages.

¹⁰ Two hundred and thirty-seven of these were examined by W. L. McAtee.

VEGETABLE FOOD.

Vegetable matter constitutes about seven-eighths (87.15 per cent) of the total food of the pintail. This is made up of the following items: Pondweeds, 28.04 per cent; sedges, 21.78; grasses, 9.64; smartweeds and docks, 4.74; arrowgrass, 4.52; musk grass and other algae, 3.44; arrowhead and water plantain, 2.84; goosefoot family, 2.58; waterlily family, 2.57; duckweeds, 0.8; water milfoils, 0.21; and miscellaneous vegetable food, 5.99 per cent.

PONDWEEDS (NALADACEAE), 28.04 PER CENT.

The pondweed, the family of plants which furnishes the largest item of food for the pintail, is the favorite also of several other species of ducks, including the gadwall and the baldpate. The latter two species, however, partake very largely of the leaves and stems of the plants, while the pintail prefers the seeds. Of the whole number of stomachs of the pintail, 254 contained seeds or other parts of widgeon grass (*Ruppia maritima*), at least four of them with from 1,000 to 1,300 seeds each. Two others contained about 2,800 seeds each of unidentified species of true pondweed (*Potamogeton*), and another held over 2,000 seeds of horned pondweed (*Zannichellia palustris*). Seeds of sago pondweed (*Potamogeton pectinatus*), small pondweed (*P. pusillus*), leafy pondweed (*P. foliosus*), and curly pondweed (*P. diversifolius*) were identified in a few instances, but pondweed seeds of which the species could not be determined were found in 271 stomachs. Seeds of horned pondweed were present in 18 stomachs, those of bushy pondweed (*Najas flexilis*) in 23, while the seeds, and occasionally leaves, of eelgrass (*Zostera marina*) were found in 93, and amounted to 4.03 per cent of the pintail's total food. This item was most abundant in the stomachs of a series of birds from the southwestern coast of Washington.

SEDGES (CYPERACEAE), 21.78 PER CENT.

The seeds of sedges are second only to the pondweeds in importance in the food of the pintail. The plants of this family often are semisubmerged, or grow in marshy situations. Probably most of the seeds are taken from the water after they have ripened and fallen, although no doubt a great many are picked from the shorter plants and those which are bent low over the water. Seeds of the common three-cornered bulrush, or three-square (*Scirpus americanus*), were identified from 155 of the pintail stomachs, those of prairie bulrush (*S. paludosus*) from 84, salt-marsh bulrush (*S. robustus*) from 29, *Scirpus cubensis* from 8, river bulrush (*S. fluvialis*) from 3, and unidentified bulrushes from 154. Seeds of saw grass (*Cladium effusum*), spike rush (*Eleocharis* sp.), chufa (*Cyperus* sp.), beaked rush (*Rhynchospora* sp.), and sedges of the genera *Fim-*



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PINTAIL (*DAFILA ACUTA*).
Male on right; female on left.



bristylis and *Carex* also were taken very frequently by these ducks. As many as 1,500 seeds of beaked rush, 3,000 of the three-square, 3,600 of spike rush, and 9,000 of *Scirpus cubensis* were counted from various single stomachs, while one contained more than 150 of the large, horned seeds of beaked rush (*Rhynchospora corniculata*).

GRASSES (GRAMINEAE), 9.64 PER CENT.

Grass remains in the pintail's food consist also very largely of seeds. Many of the stomachs contained the seeds of switchgrass (*Panicum* sp.), barnyard grass or wild millet (*Echinochloa crus-galli*), wild rice (*Zizania palustris*), cut grass (*Zizaniopsis miliacea*), salt grass (*Distichlis spicata*), and foxtail (*Chaetochloa* sp.), often in very large numbers. One was found to contain 11,500 seeds of barnyard grass, and another held nearly 4,000 of switchgrass. Included in the grass family are cultivated rice (*Oryza sativa*) and other grains. Rice was found in 52 of the pintail stomachs—24 of them from Texas, 18 from Louisiana, and 10 from Florida. Many were crammed with rice kernels, and contained nothing else, but all were taken during the months of November, December, and February, so there can be no doubt that it was all waste grain. Of the other cultivated grains, corn was found in 3 stomachs, wheat in 3, barley in 3, and oats in 1. This also probably was waste grain, with the exception of oats, taken in North Dakota in June, and a few grains of wheat taken in Colorado in March.

SMARTWEEDS AND DOCKS (POLYGONACEAE), 4.74 PER CENT.

Many of the plants of the family Polygonaceae grow in or near water and their seeds are eaten by a great many different kinds of birds. The seeds of mild water pepper (*Polygonum hydropiperoides*), found in 29 stomachs, and of water smartweed (*P. amphibium*), in 23, seem to be the favorites with the pintail. Several also had taken seeds of prickly smartweed (*P. sagittatum*), knotweed (*P. aviculare*), Pennsylvania smartweed (*P. pennsylvanicum*), water pepper (*P. hydropiper*), and other smartweeds (*P. lapathifolium*, *P. persicaria*, and *P. opelousanum*). About 12,500 seeds of a smartweed, *Polygonum punctatum*, were found in the crammed gullet and gizzard of one pintail from Alabama. Seeds of dock (*Rumex* sp.) were present in 7 gizzards.

ARROW-GRASS (*Triglochin maritima*), 4.52 PER CENT.

Arrow-grass is a plant of the marshes, muddy shores, or low meadows near salt water. The seeds are borne on erect spikes, and are the only parts of the plants commonly eaten by the birds. Eighty-eight pintail stomachs, all from the Pacific coast of Washington,

contained these seeds. They were often present in large masses, and together with the seeds of eelgrass formed the bulk of the contents of the stomachs from that region, all of which were taken during the months of October, November, and December.

MUSK GRASS (*Chara*) AND OTHER ALGAE, 3.44 PER CENT.

The stomachs of 49 pintails held at least traces of musk grass, and 8 contained other algae. A few were filled with algae alone. The fact that a duck has been feeding upon musk grass often can be detected by the presence of the small, hard reproductive cells (oögonia) which persist in the stomach after all other parts have been digested.

ARROWHEAD AND WATER PLANTAIN (ALISMACEAE), 2.84 PER CENT.

Many of the pintails shot on the delta of the Mississippi River, Louisiana, had been feeding on the tubers of an arrowhead (*Sagittaria platyphylla*), which is very abundant on the mud flats there. These tubers are known as the "delta potato," and are one of the important duck foods of that region.¹¹ The seeds of arrowheads occasionally are taken also, as well as the tubers of other species. Seeds of water plantain (*Alisma plantago-aquatica* et al.) were found in 6 stomachs.

GOOSEFOOT FAMILY (CHENOPODIACEAE), 2.58 PER CENT.

Of a series of 35 pintail stomachs collected from a point on the Gulf coast of Texas in October, 33 contained seeds of glasswort (*Salicornia ambigua*), a low, fleshy, leafless plant growing in dense colonies on mud flats too saline for other vegetation. These seeds amounted to 100 per cent of the contents of 25 of the stomachs, and averaged 93 per cent in the series of 35. Two of the stomachs contained no fewer than 28,000 seeds each. Five pintails had eaten seeds of pigweed (*Chenopodium* sp.) and one those of saltbush (*Atriplex* sp.).

WATERLILY FAMILY (NYMPHAEACEAE), 2.57 PER CENT.

The stomachs of 34 pintails contained seeds of water shield (*Brasenia schreberi*), 10 the seeds of waterlilies of the genus *Castalia*, and 6 those of the genus *Nymphaea*, which includes the yellow pondlily. One Florida stomach contained 142 seeds of water shield, 4 of a species of *Castalia*, and the remains of a large number of a species of yellow pondlily.

DUCKWEEDS (LEMNACEAE), 0.8 PER CENT.

Only 15 pintails had eaten duckweeds (*Lemna* sp.). These small plants so relished by the wood duck, form one of the lesser items in the food of the pintail.

¹¹ See Bull. No. 465, U. S. Dept. Agr., pp. 21-24, 1917.

WATER MILFOILS (HALORAGIDACEAE), 0.21 PER CENT.

Water milfoils are usually submerged plants, bearing hard, nutlike seeds in the axils of the finely dissected leaves. The seeds, and sometimes bits of the leaves, are picked off occasionally by ducks. Seeds of water milfoil (*Myriophyllum* sp.) were found in 24 of the pintail stomachs, of bottle brush (*Hippuris vulgaris*) in 12, and mermaid weed (*Proserpinaca* sp.) in 6.

MISCELLANEOUS VEGETABLE FOOD, 5.99 PER CENT.

The seeds of many species of plants not already mentioned were found in stomachs of pintails, sometimes in comparatively large series, but then only in small numbers. In this category are seeds of myrtles or bayberries (*Myrica* spp.), found in 45 gizzards; brambles (*Rubus* spp.), in 43; elders (*Sambucus* spp.), in 32; bur reed (*Spartanium* sp.), in 32; wild heliotrope (*Heliotropium indicum*), in 28; hornwort or coontail (*Ceratophyllum demersum*), in 23; crowfoots (*Ranunculus* spp.), in 17; pigweeds (*Amaranthus* spp.), in 15; hawthorns (*Crataegus* spp.), in 12; grapes (*Vitis* spp.), in 11; mallows (Malvaceae), in 10; and many others. Bits of spruce needles (*Picea* sp.) had been picked up, probably from the water, by 21 of the ducks; four pintails had eaten leaves or rootstocks of wild celery (*Vallisneria spiralis*). The remainder of the miscellaneous vegetable food consisted entirely of seeds.

ANIMAL FOOD.

The animal portion, 12.85 per cent, of the food of the pintail was made up of mollusks, 5.81 per cent; crustaceans, 3.79 per cent; insects, 2.85 per cent; and miscellaneous, 0.4 per cent.

MOLLUSKS (MOLLUSCA), 5.81 PER CENT.

Mollusks were found in 326 of the 790 pintail stomachs examined. In 44 they constituted 50 per cent or more of the contents, and in 5 they reached 100 per cent. Practically all of a large series of stomachs from the Pacific coast of Washington contained mollusk shells. Univalves (Gastropoda) predominated over bivalves (Pelecypoda) in the food of the pintail, but large numbers of small species and young of the latter were taken. In many instances mollusks could not be identified because of the great efficiency of the duck stomachs as grinding machines.

CRUSTACEANS (CRUSTACEA), 3.79 PER CENT.

Remains of crabs were found in 28 of the pintail stomachs, crawfish in 4, and shrimps in 2. Ten ducks shot near the eastern end of Long Island, New York, had been feeding very largely upon a small

crab (*Hexapanopeus angustifrons*) which frequents the beaches there. One gizzard contained the claws and other remains of at least 30 of these crabs. When crawfish are eaten by ducks, small plano-convex masses of calcareous matter known as gastroliths, supposed to be used as material for a new exoskeleton after moulting, often are found, with the fingers or claws persisting in the stomach after other parts of the crawfish are digested. Small bivalved crustaceans (Ostracoda) had been taken by 38 of the pintails, sand fleas or beach fleas (Amphipoda) by 20, and sowbugs (Isopoda) by 5.

INSECTS (INSECTA), 2.85 PER CENT.

Beetles (Coleoptera) amounting to 0.93 per cent of the total food of the pintail, consisted largely of three families, the predacious diving beetles (Dytiscidae), water scavenger beetles (Hydrophilidae), and ground beetles (Carabidae). Others represented were the snout beetles (Curculionidae), leaf beetles (Chrysomelidae), leaf chafers (Scarabaeidae), crawling water beetles (Haliplidae), rove beetles (Staphylinidae), click beetles (Elateridae), flat bark beetles (Cucujidae), and tiger beetles (Cicindelidae). Besides these there were the fragments of many unidentified beetles and the larvae of aquatic species.

Flies (Diptera) found in the pintail stomachs consisted mainly of larvae and amounted to 0.85 per cent of the total food. The following families of flies were represented: Midges (Chironomidae), in 31; brineflies (Ephydriidae), in 15; soldierflies (Stratiomyidae), in 8; crane flies (Tipulidae), in 3; horseflies (Tabanidae), in 2; and unidentified fly remains in 10 stomachs.

The larvae or nymphs, and a few adults, of dragonflies (Anisoptera) and damselflies (Zygoptera), together furnished 0.44 per cent of the pintails' food; bugs (Heteroptera), consisting chiefly of water boatmen (Corixidae), creeping water bugs (Naucoridae), and giant water bugs (Belostomatidae), amounted to 0.23 per cent; the larvae and larval cases of caddisflies (Phryganoidea), 0.2 per cent; and other insects, consisting of a few grasshoppers (Orthoptera), ants and wasps (Hymenoptera), and Mayflies (Agnatha), totaled 0.2 per cent.

MISCELLANEOUS ANIMAL FOOD, 0.4 PER CENT.

The remains of small fish (found in 16 stomachs), a frog (*Rana* sp.), mandibles of a few marine worms (*Nereis* sp.), tiny water mites (Hydrachnidae), bits of hydroids (Hydrozoa), corallines (Bryozoa and Alcyonaria), and the minute, lime-incrusted, one-celled organisms known as Foraminifera, all were included in the varied bill of fare of the pintail.

WOOD DUCK.

Aix sponsa.

PLATE VII.

The wood duck ranges in summer nearly throughout the United States, southern British Columbia, southern Saskatchewan, Ontario, New Brunswick, and Nova Scotia; it breeds casually in Cuba, and is accidental in Bermuda, Mexico, and Jamaica. In winter it occupies approximately the southern half of its summer range. Its southward migration is accomplished chiefly in October, and it moves northward rather early in spring, reaching the latitude of central Iowa usually about March 20 and southern Manitoba April 15.

As its name implies, the wood duck inhabits secluded woodland ponds and lakes and timbered streams. It makes its nest in a natural cavity in a tree, from which the mother duck takes the young soon after they are hatched and carries them one by one in her beak to the water.¹² The adult male is the most brilliantly colored of all American ducks, and probably is as fine in appearance as any in the world. Its most striking feature is a large bright green and purple crest, striped with white, the rest of the head being of the same colors. The throat is white; on each side of the body is a row of black and white crescents, and across the shoulders are black and white bars. The upperparts are iridescent greenish or brownish black, and the breast is rich chestnut, spotted with white. The plumage of the female presents much the same general pattern as that of the male, but lacks most of its bright coloration.

FOOD HABITS.

Although the wood duck often is seen in the haunts of other ducks on open stretches of water or marshy land, its usual feeding grounds are along the banks of the wooded streams and ponds near which it nests in summer. Here it not only feeds upon the seeds and other parts of the plants which grow in or near the water, but often it wanders far out into the drier parts of the woods to pick up acorns, nuts, grapes, and berries, and the seeds of various trees and shrubs. Most of the insects and of the other animal food taken, however, are kinds which either inhabit the water itself or live on plants which grow in or near the water. Some terrestrial species are caught, but it is probable that most of these are picked up from the surface of the water, as the ducks are not fitted for successfully catching active insects on land. They are expert, however, in catching those which fly low over the water or glide over its surface, and obtain the kinds which swim beneath the surface (as well as

¹² Kingsford, E. G., Wood Duck Removing Young from the Nest: Auk, XXXIV., pp. 335-336, 1917.

the seeds and other parts of submerged plants) by half-diving, after the manner of the mallard and several other ducks.

The stomachs of 413¹³ wood ducks were available for examination. Six stomachs were rejected on account of the too meager or uncertain nature of their contents, and seven more from ducks collected during January, May, and June, because they were not sufficient in number adequately to represent those months. None were taken during July; so that the 399 stomachs from which final results were computed represent only the months from August to December, and from February to April, inclusive. There is no reason why the food for January should not be similar to that of the other winter months; in summer, however, the percentage of animal food no doubt is somewhat higher. Stomachs were collected from 24 States and the District of Columbia, from Maine and Florida to Oregon and California, and from the Province of Ontario to Texas; but about five-eighths (268) of the whole number were taken in Louisiana. The bulk of the wood ducks, now nowhere abundant as breeders, inhabit the Mississippi Valley, and in winter they find ideal feeding and living conditions in the cypress swamps and wooded lakes and lagoons of the States bordering the Mississippi from about the mouth of the Ohio River southward.

VEGETABLE FOOD.

More than nine-tenths (90.19 per cent) of the food of the wood duck consists of vegetable matter. This high proportion of vegetable food is very similar to that taken by the mallard. With the wood duck it is quite evenly distributed among a large number of small items, chief among which are the following: Duckweeds, 10.35 per cent; cypress cones and galls, 9.25; sedge seeds and tubers, 9.14; grasses and grass seeds, 8.17; pondweeds and their seeds, 6.53; acorns and beechnuts, 6.28; seeds of waterlilies and leaves of water shield, 5.95; seeds of water elm and its allies, 4.75; of smartweeds and docks, 4.74; of coontail, 2.86; of arrow-arum and skunk cabbage, 2.42; of bur marigold and other composites, 2.38; of buttonbush and allied plants, 2.25; of bur reed, 1.96; wild celery and frogbit, 1.31; nuts of bitter pecan, 0.91; grape seeds, 0.82; and seeds of swamp privet and ash, 0.72 per cent. The remaining 9.4 per cent was made up of a large number of minor items.

DUCKWEEDS (LEMNACEAE), 10.35 PER CENT.

Whenever present in the feeding grounds of the wood duck, duckweeds probably are its favorite food. Each individual plant consists simply of a small fleshy leaf, disk shaped or nearly so, floating on the surface of the water, with one or more simple roots dangling.

¹³ Eighty-six of these were examined by W. L. McAtee.



BUTOM

WOOD DUCK (*AIX SPONSA*).
Male on right; female on left.



Duckweeds are especially abundant on the still waters of southern cypress swamps, often covering the entire surface and furnishing an abundant supply of food for the ducks wintering there. - The stomachs of many of the wood ducks taken in such localities in Louisiana and Missouri were filled almost entirely with duckweed plants, and the gullets also of several of them were crammed. A few ducks from other localities, as Arkansas, Illinois, New York, and Ontario, had taken this food in considerable quantities. Altogether, 99 of the wood ducks had been feeding upon greater duckweed (*Spirodela polyrhiza*) and 187 on other duckweeds (*Lemna* spp.).

PINE FAMILY (PINACEAE), 9.25 PER CENT.

The pine family was represented in the wood duck stomachs entirely by cone scales and galls from the bald cypress (*Taxodium distichum*), with possibly a few from pond cypress (*T. ascendens*). This peculiar diet is indulged in by this duck to a much greater extent than by any other, or probably by any other bird. The cones of cypress are about an inch in diameter, compact and nearly spherical, and when fully mature break up into angular woody scales, each containing a seed. It is these scales which the ducks pick up and which when ground by the powerful gizzards yield a starchy food material in the seeds. Several kinds of insect galls found on different parts of cypress trees also were eaten by the ducks. The kind most commonly taken was a hard, spherical gall made in the cone by a species of cecidomyid fly (*Retinodiplosis taxodii*). Cypress galls of various kinds were found in 35 of the stomachs, while 183 contained cone scales, some to the extent of 100 per cent of the contents.

SEDGES (CYPERACEAE), 9.14 PER CENT.

Sedge seeds are common articles of food of the wood duck, though not so much so as of most of the ducks which inhabit open marshes. A species of bulrush (*Scirpus cubensis*) which grows in swamps in the Gulf States far outweighed in importance any of the other sedges identified in the stomachs examined. The seeds of this plant were found in 47 stomachs, in several instances from 3,000 to more than 5,000 being present. Fifteen wood ducks had eaten the large, beaked seeds of pollywog or beaked rush (*Rhynchospora corniculata*). In a series of 3 stomachs from Okefenokee Swamp, Georgia, these seeds constituted 10, 17, and 35 per cent, respectively, of the contents. The small, hard, spherical seeds of saw grass (*Cladium effusum*) were present in 15 stomachs, those of nut rush (*Scleria* sp.) in 3. Seeds of chufas (*Cyperus* spp.) were found in 45 stomachs, usually in small numbers, and in one stomach from Minnesota was one large tuber of chufa (*Cyperus esculentus*). Seeds of the genus

Carex were commonly taken, usually in small numbers; unidentified kinds were present in 33 gizzards, the seeds of panicked sedge (*Carex decomposita*) in 21, and hop sedge (*C. lupuliformis*) in 8. Other sedge seeds found were those of river bulrush (*Scirpus fluviatilis*), *Fimbristylis*, spike rush (*Eleocharis* sp.), beaked rush (*Rhynchospora* sp.), and unidentified sedges.

GRASSES (GRAMINEAE), 8.17 PER CENT.

Chief among the grasses which contribute to the food of the wood duck is wild rice (*Zizania palustris*). Its seeds are fed upon by practically all the fresh water ducks, and it presents such an attractive source of food supply as to entice even the wood duck from its secluded haunts to the open marshes where the wild rice grows. According to Kumlien and Hollister,¹⁴ the wood duck, in fall, "resorts to the great wild rice marshes, and while the rice lasts that seems to be its principal food." Wild rice had been eaten by 17 of the wood ducks examined, and when present usually furnished the bulk of the food. The stomach and gullet of one duck shot at Point Pelee, Ontario, contained no fewer than 1,200 seeds of wild rice, with remains of others. Another wood duck, taken at Sand Point, Mich., in August, had filled its craw and gizzard with about 400 flowers of the plant, whole heads of which had been swallowed. An article of food which seems to be very much relished by the ducks wherever found is the seeds of meadow grass (*Panicularia nervata*). Of a series of 22 wood ducks taken at Caruthersville, in extreme southeastern Missouri, 17 had been feeding upon these seeds. The stomachs and gullets of 7 contained, respectively, from 5,300 to 10,000 seeds to each individual, the seeds constituting from 75 to 96 per cent of the food. The seeds of a switchgrass (*Panicum*, subgenus *Dichanthelium*) were found in considerable quantities in several of the stomachs from Louisiana, some of which contained in addition remains of the stems and leaves of the same grass. In addition to the grasses already mentioned, the seeds of other switchgrasses (*Panicum* spp.), wild millet (*Echinochloa crus-galli*), cut-grass (*Zizaniopsis miliacea*), rice cut-grass (*Homalocenchrus oryzoides*), and love grass (*Eragrostis* sp.) were identified. The stomach of one wood duck taken near Chicago, Ill., in October, was filled with corn, and one from Louisiana contained traces of cultivated rice.

PONDWEEDS (NAIADACEAE), 6.53 PER CENT.

In the pondweeds is another family of plants which is important as a source of food for many species of ducks and to secure which the wood duck departs to some extent from its normal feeding habits.

¹⁴ Kumlien, L., and N. Hollister, The Birds of Wisconsin: Bull. Wisconsin Nat. Hist. Soc., III, p. 21, 1903.

Seeds or other parts of five species of true pondweeds (*Potamogeton americanus*, *P. natans*, *P. heterophyllus*, *P. zosterifolius*, and *P. pectinatus*) each were found in from one to three stomachs, and unidentified pondweeds in 44. The gullet and stomach of one wood duck taken at Rush Lake, Michigan, in August, 1908, contained about 350 tubers of a species of *Potamogeton*. The gizzards of three from Delavan Lake, Wisconsin, were filled with the winter buds of eelgrass pondweed (*Potamogeton zosterifolius*). Only one wood duck had eaten seeds of bushy pondweed (*Najas flexilis*), and the seeds and leaves of widgeon grass (*Ruppia maritima*), which form so important an element of food for the gadwall and widgeon, were entirely lacking.

BEECH FAMILY (FAGACEAE), 6.28 PER CENT.

Acorns and beech nuts furnish one of the most important items of the wood duck's food, and had the collection of stomachs available been from localities more evenly distributed throughout its range, the percentage of this food very probably would have been much larger. As it was, 3 of the gizzards contained beech nuts and 19 contained acorns. Of the latter, 5 species were identified: Red oak (*Quercus rubra*) from 1 stomach, pin oak (*Q. palustris*) from 5, water oak (*Q. nigra*) from 2, black-jack (*Q. marylandica*) from 2, and valley oak (*Q. lobata*) from 1, while fragments of acorns found in 8 gizzards were not identified. Several of the stomachs containing acorns were crammed with them, the gullet and gizzard of one from Arkansas containing 15 entire acorns of pin oak, with fragments of one or two others. The wood duck's habit of eating acorns is well known, many writers testifying to its fondness for this kind of food. According to the late D. G. Elliot,¹⁵ the wood duck is called "acorn duck" in Louisiana. Wilson and Bonaparte,¹⁶ in 1831, wrote that its food "consists principally of acorns, seeds of the wild oats, and insects." Kumlien and Hollister¹⁷ state that the wood duck "takes to the oak groves about the streams and lakes, and seems to be especially partial to the acorns of the bur oak. These it eats in large quantities."

Without doubt the wood duck's usual method of gathering acorns is by picking them up off the ground or from the water. However, one author, Mr. N. S. Goss,¹⁸ is authority for the statement that, "Their food consists chiefly of insect life, the tender shoots and seeds of aquatic plants, grains, wild grapes and acorns, which they gather as well from the vines and tree tops as upon the ground. . . ."

¹⁵ Elliot, D. G., Wild Fowl of North America, p. 87, 1898.

¹⁶ Wilson, A., and C. L. Bonaparte, Amer. Ornith., III, p. 203, 1831.

¹⁷ Kumlien, L., and N. Hollister, op. cit., III, p. 21, 1903.

¹⁸ Goss, N. S., History of the Birds of Kansas, p. 73, 1891.

WATERLILY FAMILY (NYMPHAEACEAE), 5.95 PER CENT.

Seeds of waterlilies are quite frequently eaten by ducks. Twelve of the wood ducks had eaten seeds of yellow pondlilies, of which two species, the cowlily (*Nymphaea advena*) and the small yellow pondlily (*Nymphaea microphylla*) were identified; 10 contained seeds of white waterlilies, of which 2 species (*Castalia odorata* and *C. tuberosa*) were identified; and 11 contained seeds of water shield (*Brasenia schreberi*). Of the latter, one contained 380 seeds; and the stomach and distended gullet of a wood duck taken near Chicago, Ill., held 577 seeds of a white waterlily (*Castalia tuberosa*), with fragments of several more, in addition to other items. Two stomachs from southeastern Missouri contained quantities of the remains of stems and leaves of Carolina water shield (*Cabomba caroliniana*).

NETTLE FAMILY (URTICACEAE), 4.75 PER CENT.

The nettle family of plants was represented in the wood duck stomachs chiefly by the seeds of water elm (*Planera aquatica*),¹⁹ which had been taken by 66 of these ducks. Many ducks in Louisiana had gorged themselves upon these large seeds, their gullets and gizzards being crammed. One wood duck had devoured nearly 300 at its last meal. A series of 13 gizzards from Avoyelles Parish, La., contained seeds of water elm to the average extent of over 48 per cent, most of the remainder of the food consisting of the seeds of coontail (*Ceratophyllum demersum*). The stomach of a duck from southeastern Missouri was nearly filled with the seeds of another elm (*Ulmus* sp.). Another, from Alabama, contained the remains of several red mulberries and eight of the hard drupes of hackberries (*Celtis* sp.), both of which belong to this family of plants. The small seeds of false nettle (*Boehmeria cylindrica*) were present in three stomachs.

SMARTWEEDS (POLYGONACEAE), 4.74 PER CENT.

In addition to a few seeds of dock (*Rumex* sp.), which were found in seven gizzards, and unidentified smartweeds, in 17, ten species of smartweed seeds were identified as having been eaten by the wood ducks. Of these, water smartweed (*Polygonum amphibium*) and mild water pepper (*P. hydropiperoides*) were the most commonly taken. The largest number of smartweed seeds found in any one wood duck stomach was taken from a bird collected in Avoyelles Parish, La., which had eaten over 1,100 of the small black seeds of *Polygonum opelousanum*.

COONTAIL (*Ceratophyllum demersum*), 2.86 PER CENT.

Coontail is a rootless, submerged plant, the much-branched stems of which bear bushy masses of small whorled leaves. Near the ends

¹⁹ For a full description of this plant and its seeds, see Bull. 205, U. S. Dept. Agr., pp. 9-12, 1915.

of the branches are borne the fruits, consisting of hard, oblong, flattened seeds a little more than one-eighth of an inch long, and usually bearing on their outer covering from one to three woody spines. A few ducks, especially the gadwall and widgeon, relish the foliage of coontail, but most species, including the wood duck, prefer the seeds. Only a very few stomachs of this species contained foliage of coontail, and in these cases it was present in such small quantities as to indicate that it had been taken accidentally. The plant has a very wide distribution, and is found throughout North America except in the extreme north. The seeds were found most commonly, however, in the stomachs of wood ducks from the Southern States. In a series of 65 gizzards from Moreauville, La., all but two of which contained seeds of coontail, they averaged about $12\frac{1}{2}$ per cent of the total food. In another series, 13 in number, from Avoyelles Parish, La., seeds of coontail amounted to more than 38 per cent. The largest number found in one gizzard was 127, with fragments of others.

ARUM FAMILY (ARACEAE), 2.42 PER CENT.

The large, starchy seeds of arrow-arum (*Peltandra virginica*) were present in 5 of the wood-duck stomachs examined. Three of these from Portage Lake, Michigan, were well filled, one containing 51 seeds and remains of others, both crop and gizzard being crammed. In some localities these seeds are a very important item in the wood duck's food. In January, 1914, Lord William Percy found wood ducks in the Everglades of Florida feeding almost exclusively on the seeds of *Peltandra*. C. P. Alexander, writing of a visit to the Kinloch Gun Club, South Carolina, September 5, 1915, says: "As we approached, * * * several hundred summer ducks were feeding and flew up in small groups of 2 to 12. Upon examining the places from which they arose I found thousands of the seeds of *Peltandra* all neatly shelled out and the outer coats floating in small groups in the water. The spathes from which they were taken occurred by the score, each with a large hole torn in the side. Two of the ducks were shot and the craws were full of *Peltandra* seed. There can be no doubt of the importance of this plant as a food for *Aix* at least." The gullet and stomach of one wood duck from Connecticut contained 31 seeds of the skunk cabbage (*Symplocarpus foetidus*), with remains of several more.

COMPOSITES (COMPOSITÆ), 2.33 PER CENT.

The flat, spined seeds of bur marigold (*Bidens* sp.), known as beggar-ticks or stick-tights, were present in 25 gizzards, sometimes in considerable numbers; three from Avoyelles Parish, La., were nearly filled with them. Two ducks collected in northeastern Kansas had filled up on the seeds of giant ragweed (*Ambrosia trifida*).

MADDER FAMILY (RUBIACEAE), 2.25 PER CENT.

One of the staple articles of food of the ducks feeding in the southern swamps is the seeds of buttonbush (*Cephalanthus occidentalis*). Of the total of 413 stomachs of wood ducks, 192 contained these seeds. They were present in 65 per cent of the stomachs from Louisiana, usually in small numbers. Occasionally, however, several hundred were present in single stomachs, in which they made as much as 75 or even 90 per cent of the contents. Remains of the seeds of buttonweed (*Diodia virginiana*) were found in 6 stomachs; those of cleavers (*Galium* sp.), in one.

BUR REEDS (SPARGANIACEAE), 1.96 PER CENT.

The hard, nutlike seeds of bur reeds (*Sparganium* spp.) were present in 53 of the wood duck stomachs. Bur reeds are aquatic plants with ribbon-shaped leaves and with seeds borne in clusters resembling burs at the ends of the branches. When these seeds are found in duck gizzards the outer coverings are usually worn off, but the hard kernels persist for some time. In 17 instances the seeds were identified as those of the broad-fruited bur reed (*Sparganium eurycarpum*).

FROGBIT FAMILY (HYDROCHARITACEAE), 1.31 PER CENT.

Remains of the many-seeded fruits of frogbit were found in 12 wood ducks' stomachs. Several full stomachs from Louisiana contained this food to the extent of from 65 to 90 per cent of their contents. The plant is aquatic, and its berries are fed upon by many species of ducks. Four wood ducks had been feeding upon wild celery (*Vallisneria spiralis*). One of these, taken from the shallows at the mouth of the Susquehanna River, in Maryland, had swallowed 30 of the sprouting winter buds of the plant, and another from Delavan, Wis., had filled up on the same food. This plant is a much more important element in the food of some of the deep-water ducks, as the red-head and the canvas-back, which obtain the winter buds and rootstocks by diving.

WALNUT FAMILY (JUGLANDACEAE), 0.91 PER CENT.

The powerful crushing and grinding ability of the wood duck's gizzard is shown by the presence in 76 of the stomachs examined of fragments of the nuts of the bitter pecan (*Hicoria aquatica*). These nuts have as hard a shell as any of the northern hickory nuts, yet they are broken as they enter the gizzard and before they can possibly have been exposed to the full crushing power of that organ.

All of the bitter pecans identified were from ducks taken in Louisiana. The entire food of one bird from Mansura, La., consisted of one whole pecan with fragments of several others. Usually pecans amounted to from 5 to 20 per cent of the stomach contents.

VINE FAMILY (VITACEAE), 0.82 PER CENT.

The estimated average percentage, 0.82, of the remains of grapes actually found in the wood duck stomachs, undoubtedly is much less than the true proportion of grapes consumed, for the skins, pulp, and juice are very quickly digested, leaving nothing but the seeds, or much more commonly, fragments of seeds, to show that grapes had been eaten. It is probable that most of these grapes are picked up from the ground in the woods, though some may be taken from the vines. Traces of grapes (always in the form of seeds or seed-fragments) were present in 141 of the wood duck stomachs.

OLIVE FAMILY (OLEACEAE), 0.72 PER CENT.

Two wood ducks had eaten seeds of ash (*Fraxinus americana* and other species). The remainder of the food from this family of plants consisted of the seeds of swamp privet (*Adelia acuminata*), which were present in 31 stomachs. This is a favorite food for wild ducks in some southern localities, according to the testimony of numerous hunters. "Wood ducks in particular are said to feed extensively upon its seeds. Weeks before other species of ducks arrive these birds are abundant in the country where swamp privet grows and are said to consume most of the crop of seeds, leaving little for other ducks."²⁰ The plant is a shrub or small tree, and the seed, which has a fibrous, ridged coat, is inclosed in a watery blue berry from one-half to three-fourths of an inch in length. These berries ripen in May and June and fall into the water; many of them are picked up from the bottom by the ducks later in the season. The swamp privet grows in the same kind of localities as the water elm, and its seeds usually were found in company with the seeds of that plant in the stomachs of wood ducks. One stomach and distended crop were found which held 157 of these large seeds, with remains of several more. A sprig of swamp privet was sent to the Biological Survey by C. G. Wright, of Dallas, Tex., with the statement that it was grown from seed taken from a wood duck's gizzard, which was absolutely full of them.

MISCELLANEOUS VEGETABLE FOOD, 9.4 PER CENT.

A great number of smaller items, each of which amounted to less than 1 per cent, made up the remainder of the wood duck's vegetable food. In some localities the ducks had fed upon the tubers and seeds of arrowheads (*Sagittaria latifolia* and other species); and three from Caruthersville, Mo., had stuffed themselves with the stems, leaves, and rootstocks of a crowfoot (*Ranunculus* sp.). Three taken in Okefenokee Swamp, Georgia, in December, 1916, had been feeding upon the crimson rootstocks of red-root or paint-root (*Gyrotheca*

²⁰ McAtee, W. L., Eleven Important Wild-duck Foods, Bull. No. 205, U. S. Dept. of Agr., pp. 12-13, 1915.

tinctoria) to the extent of 50, 60, and 70 per cent, respectively, of their stomach contents. These roots are said to be fed upon quite extensively by other waterfowl in that locality.

Several stomachs from southeastern Missouri contained from 1,000 to nearly 10,000 seeds each of lizard's-tail (*Saururus cernuus*), while others, chiefly from Louisiana swamps, held thousands of the small seeds of the primrose willow (*Jussiaea* sp.). The flat seeds of water-penny (*Hydrocotyle* sp.) were present in 44 stomachs, but never in large numbers. Among the other aquatic plants whose seeds were commonly taken were the water milfoils (*Myriophyllum* sp., *Proserpinaca* sp., and *Hippuris vulgaris*), pickerel weed (*Pontederia cordata*), fog-fruit (*Lippia* sp.), and swamp loosestrife (*Decodon verticillatus*). Seeds of wild heliotrope (*Heliotropium indicum*) and croton (*Croton* sp.) were found in 22 and 16 stomachs, respectively.

Many woodland shrubs, trees, and vines in addition to those already mentioned were represented by their seeds in a few stomachs each, or by only a few seeds in many stomachs. These included hollies (*Ilex* spp.), sumachs (*Rhus* spp.), supple jack (*Berchemia scandens*), buckthorn (*Rhamnus cathartica*), tupelo (*Nyssa sylvatica* and *N. aquatica*), dogwoods (*Cornus* spp.), storax (*Styrax* sp.), myrtles (*Myrica cerifera* and other species), hawthorns (*Crataegus* spp.), brambles (*Rubus* spp.), hornbeam (*Carpinus caroliniana*), sweet gum (*Liquidambar styraciflua*), greenbriar (*Smilax* sp.), and a few others.

ANIMAL FOOD.

The wood duck's animal food, which amounted to 9.81 per cent of the total, consisted chiefly of the following items: Dragonflies and damselflies and their nymphs, 2.54 per cent; bugs, 1.56; beetles, 1.02; grasshoppers and crickets, 0.23; flies and ants, bees, and wasps, 0.07; miscellaneous insects, 0.97; spiders and mites, 0.63; crustaceans, 0.08; and miscellaneous animal matter, 2.71 per cent. Thus, nearly two-thirds of the animal food consisted of insects.

DRAGONFLIES (ANISOPTERA); AND DAMSELFLIES (ZYGOPTERA), 2.54 PER CENT.

The food of 72 wood ducks included the remains of dragonflies and damselflies or their nymphs. The nymphs or larvae are much more commonly taken than the adults, as they are easier to catch. The food from this group of insects averaged 10.44 per cent of the total for 9 wood ducks taken in April, and 8.75 per cent for the 16 in March. During the remainder of the year much smaller quantities were taken.

BUGS (HETEROPTERA AND HOMOPTERA), 1.56 PER CENT.

Bugs, chiefly aquatic, are a very constant item of food for the wood duck, at least 17 families being represented in the contents of the stomachs examined. Of these the most important were the creep-

ing water bugs (Naucoridae), of which the small, flat, predacious bugs of the genus *Pelocoris* had been taken by 43 of the ducks; the giant water bugs (Belostomatidae), represented by the genus *Belostoma* in 37 stomachs; water striders (Gerridae), found in 30; back-swimmers (Notonectidae), in 20; and water boatmen (Corixidae), in 15. Bugs of the last three families mentioned are without exception very active in their movements on or in the water, and their presence in so many stomachs of the wood duck no doubt is accounted for by their great abundance in lakes and rivers throughout most of North America. One wood duck taken at Alden, Wis., in August, 1908, had been feeding upon a species of plant louse (*Rhopalosiphum nymphaeae*) which in certain states of its development inhabits the leaves of waterlilies. The bird's gizzard contained about 1,600 of these plant lice, as well as other insects and seeds.

BEETLES (COLEOPTERA), 1.02 PER CENT.

Beetles of at least 15 families were represented in the food of the wood ducks examined. Of these the water scavenger beetles (Hydrophilidae), predacious diving beetles (Dytiscidae), and leaf beetles (Chrysomelidae) were most commonly taken. The first two families mentioned, as their names imply, are strictly aquatic, while the third was represented almost entirely by beetles of the genus *Donacia*, many of which feed upon aquatic plants, such as the pondlily, spatterdock, etc. Twenty-three of these beetles (*Donacia cincticornis*) were found in one stomach, together with a large number of seeds of the tuberous white waterlily (*Castalia tuberosa*), the plant on which they probably were captured. Two other strictly aquatic families, the whirligig beetles (Gyrinidae) and crawling water beetles (Haliplidae) were well represented. Six genera of ground beetles (Carabidae) were identified, and the leaf chafers (Scarabaeidae), long-horned beetles (Cerambycidae), and snout beetles (Curculionidae) had been eaten in considerable numbers. The fact that scarabaeid beetles have been eaten is often detected by the presence of small, hard grinding plates from their jaws, which frequently persist in bird stomachs long after all other parts of the beetles have been digested. Peculiar little silken cases containing eggs of water scavenger beetles, usually attached to a submerged leaf or to the body of the female beetle herself, are not infrequently found in duck stomachs. In two from Louisiana they made up 70 and 77 per cent, respectively, of the total contents.

GRASSHOPPERS, CRICKETS, ETC. (ORTHOPTERA), 0.23 PER CENT.

Grasshoppers of the genus *Orchelimum* were found in the stomachs of 11 wood ducks from Missouri; 39 mandibles, representing at least 20 grasshoppers, were present in one stomach; 8 wood ducks had eaten grouse locusts (Tettiginae).

FLIES (DIPTERA); AND ANTS, BEES, AND WASPS (HYMENOPTERA), 0.07 PER CENT.

Most of the flies eaten by wood ducks were in the larval form. Larvae of soldierflies (Stratiomyidae) predominated, having been taken by 33 of the ducks, while the gnats and midges (Chironomidae), crane flies (Tipulidae), flowerflies (Syrphidae), and the Scatophagidae were sparingly represented. Ants were commonly eaten, but always singly or in small numbers, never constituting a very large percentage of the total food. Seven genera were identified, *Crematogaster* and *Camponotus* predominating. Wasps (Vespoidea), parasitic wasps (Ichneumonoidea), sawflies (Tenthredinoidea), bees (Apoidea), chalcids (Chalcidoidea), and serphoids (Serphoidea) also were occasionally taken.

MISCELLANEOUS INSECTS, 0.97 PER CENT.

Prominent among the miscellaneous insect food of the wood ducks were the caterpillars and chrysalides of moths and butterflies (Lepidoptera), and the larvae and larval cases of caddisflies (Phryganoidea). One stomach examined contained no fewer than 85 noctuid moths, many of them with eggs. This family includes the cutworm moths, and practically all of its members are injurious to cultivated crops. A few Mayfly nymphs (Agnatha), termites (Isoptera), unidentified larvae, pupae, and galls, etc., were included among the miscellaneous insects.

SPIDERS AND MITES (ARACHNIDA), 0.63 PER CENT.

The wood duck's taste for spiders is quite marked. Several full stomachs from southern localities contained remains of from 20 to 40 spiders, these in some cases constituting as much as 75 or 80 per cent of the contents. Leathery or silken cases containing spider eggs occasionally are taken, and tiny water mites (Hydrachnidae) were found in 5 stomachs.

MISCELLANEOUS ANIMAL FOOD, 2.79 PER CENT.

Contrary to the habit of most other ducks, the wood duck pays little attention to mollusks, probably because they are not plentiful in its usual haunts. A very few snails and small bivalves were found in the stomachs examined. Crustaceans (0.08 per cent) were also scarce, being represented by a few beach fleas (Amphipoda), sowbugs (Oniscidae), water asels (Asellidae), and occasional claws of crawfish (Astacidae). Remains of small fishes, found in 5 stomachs; bones of frogs, in 2; 2 centipedes, and a few of the reproductive buds, or statoblasts, of fresh-water bryozoa, complete the list of food items.

TABLE I.—Items of vegetable food identified in the stomachs of the ducks treated in this bulletin and the number of stomachs in which found.

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined	417	255	653	319	41	790	413
SUBKINGDOM EUTHALLOPHYTA.							
Unidentified algae	29	8	7	4		8	4
<i>Oedogonium</i> sp.		1					
<i>Spirogyra</i> sp.	3	2					
<i>Chara</i> sp. (musk grass)	22	13	89	31	1	49	1
<i>Nitella</i> sp.		1					
Unidentified lichens							1
SUBKINGDOM PTERIDOPHYTA.							
Marsileaceae.							
<i>Marsilea</i> sp. (pepperwort)						2	
Equisetaceae.							
<i>Equisetum</i> sp. (horsetail)		1	1				
SUBKINGDOM SPERMATOPHYTA.							
Pinaceae.							
<i>Picea</i> sp. (spruce), needles						21	
<i>Taxodium distichum</i> (bald cypress), cone scales	6	1	5				181
<i>Taxodium distichum</i> (bald cypress), galls							35
<i>Taxodium</i> sp. (cypress)							2
Sparganiaceae.							
<i>Sparganium eurycarpum</i> (bur reed)							17
<i>Sparganium angrocladum</i> (bur reed)				2			1
<i>Sparganium</i> sp. (bur reed)	2	10	42	39	1	32	35
Naiadaceae.							
Unidentified	8						
<i>Potamogeton natans</i> (floating pondweed)				1			1
<i>Potamogeton americanus</i> (long-leaved pondweed)							1
<i>Potamogeton heterophyllus</i> (variable pondweed)							1
<i>Potamogeton perfoliatus</i> (curly pondweed)			1				
<i>Potamogeton zosterifolius</i> (eelgrass pondweed)							3
<i>Potamogeton fresii</i> (Fries pondweed)	1						
<i>Potamogeton pusillus</i> (small pondweed)	3	3	4			3	
<i>Potamogeton diversifolius</i> (curly pondweed)						1	
<i>Potamogeton foliosus</i> (leafy pondweed)						1	
<i>Potamogeton pectinatus</i> (sago pondweed)	9	5	7		1	10	2
<i>Potamogeton</i> sp. (unidentified pondweeds)	142	94	248	150	32	271	44
<i>Ruppia maritima</i> (widgeon grass)	112	92	111	87	16	254	
<i>Zannichellia palustris</i> (horned pondweed)	20	8	10	2	10	18	
<i>Zostera marina</i> (eelgrass)	3	10	3	3		93	
<i>Najas marina</i> (large bushy pondweed)				1			
<i>Najas flexilis</i> (bushy pondweed)	17	9	27	17		23	1
Juncaginaceae.							
<i>Triglochin maritima</i> (arrow-grass)		2	19			88	1
Alismaceae.							
Unidentified						2	
<i>Sagittaria latifolia</i> (wapato)				1			2
<i>Sagittaria teres</i> (slender arrowhead)						2	
<i>Sagittaria platyphylla</i> (delta potato)	45					76	
<i>Sagittaria</i> sp. (unidentified arrowheads)		2	2	4		4	5

TABLE I.—*Items of vegetable food identified in the stomachs of the ducks treated in this bulletin and the number of stomachs in which found—Continued.*

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
SUBKINGDOM SPERMATOPHYTA —Continued.							
Alismaceae—Continued.							
<i>Alisma plantago-aquatica</i> (water plantain).....			3	1		3	
<i>Alisma subcordatum</i> (American water plantain).....			1				
<i>Alisma</i> sp. (water plantain).....			1	1		3	
Hydrocharitaceae.							
<i>Philotria canadensis</i> (waterweed).....		1					
<i>Philotria</i> sp. (waterweed).....	1			2			
<i>Vallisneria spiralis</i> (wild celery).....	3	12		1		4	4
<i>Vallisneria</i> sp. (wild celery).....			2	1			
<i>Limnobium spongia</i> (frogbit).....			3			4	12
Gramineae.							
Unidentified grasses.....	5	16	37	24	3	32	15
<i>Paspalum</i> sp.....		1	4			2	
<i>Syntherisma sanguinalis</i> (crab grass).....	1						
<i>Panicum capillare</i> (tumble weed).....						1	
<i>Panicum repens</i>	4						
<i>Panicum</i> subgenus <i>Dichanthelium</i>							19
<i>Panicum</i> sp. (switch grass).....	9	11	59	18		25	2
<i>Panicum obtusum</i> (range grass).....		1					
<i>Echinochloa crus-galli</i> (wild millet).....	1		14	1		9	1
<i>Echinochloa colona</i> (jungle rice).....			1				
<i>Echinochloa</i> sp. (cockspur grass).....				1		1	
<i>Chaetochloa glauca</i> (foxtail).....	1		3	5		3	
<i>Chaetochloa viridis</i> (green foxtail).....				1		2	
<i>Chaetochloa</i> sp. (foxtail).....			6	8		23	
<i>Zizania palustris</i> (wild rice).....		5	18	22		8	17
<i>Zizaniopsis miliacea</i> (cut-grass).....	1		8	1		6	2
<i>Homalocenchrus oryzoides</i> (rice cut-grass).....	1		3	9		4	4
<i>Oryza sativa</i> (cultivated rice).....	19	1	21	12		52	1
<i>Spartina glabra</i> , var. <i>pilosa</i> (salt-marsh grass).....						1	
<i>Spartina</i> sp. (salt-marsh grass).....	1		1	1		4	
<i>Phleum alpinum</i> (mountain timothy).....			1				
<i>Sporobolus</i> sp. (rush-grass).....				1			
<i>Agrostis</i> sp. (bent grass).....			1				
<i>Beckmannia erucaeformis</i> (Beckmann grass).....			1				
<i>Cynodon dactylon</i> (Bermuda grass).....						1	
<i>Distichlis spicata</i> (salt grass).....	3	5	3			33	
<i>Monanthochloë littoralis</i>	1		16	13	5	6	
<i>Eragrostis</i> sp. (love grass).....							1
<i>Poa</i> sp. (spear grass).....	5					1	
<i>Panicularia nervata</i> (meadow grass).....							17
<i>Panicularia</i> sp. (meadow grass).....	1						
<i>Puccinellia nuttalliana</i>				3			
<i>Festuca</i> sp. (fescue grass).....						1	
<i>Avena sativa</i> (cultivated oats).....						1	
<i>Hordeum vulgare</i> (cultivated barley).....	1					3	
<i>Hordeum pusillum</i>	2	1					
<i>Triticum vulgare</i> (cultivated wheat).....			1			3	
<i>Zea mays</i> (cultivated corn).....	1		1	1		3	1

TABLE I.—Items of vegetable food identified in the stomachs of the ducks treated in this bulletin and the number of stomachs in which found—Continued.

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon-teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
SUBKINGDOM SPERMATOPHYTA —Continued.							
Cyperaceæ.							
Unidentified sedges.....	43	20	50	27	7	47	5
<i>Cyperus esculentus</i> (chufa).....							1
<i>Cyperus</i> sp. (chufa).....	31	5	48	45		29	45
<i>Dichromena</i> sp.....			1				
<i>Dulichium arundinaceum</i> (three-ways sedge).....				1			
<i>Eleocharis</i> sp. (spike rush).....	13	19	45	33	10	45	2
<i>Fimbristylis</i> sp.....	5	4	90	40		61	8
<i>Scirpus pauciflorus</i> (few-flowered bulrush).....						5	
<i>Scirpus americanus</i> (three-square).....	150	37	121	10	3	155	
<i>Scirpus paludosus</i> (prairie bulrush).....	27	12	46	7	12	24	
<i>Scirpus robustus</i> (salt-marsh bulrush).....	24		40	2		24	
<i>Scirpus fluviatilis</i> (river bulrush).....	2	5	5	18		3	4
<i>Scirpus cubensis</i> (bulrush).....	2		13			8	47
<i>Scirpus validus</i> (great bulrush).....			38	2			
<i>Scirpus</i> sp. (unidentified bulrushes).....	47	24	205	184	17	154	16
<i>Fuirena squarrosa</i> (umbrella-grass).....						1	
<i>Fuirena</i> sp. (umbrella-grass).....						1	
<i>Rhynchospora corniculata</i> (beaked rush).....			1			7	15
<i>Rhynchospora</i> sp. (beaked rush).....			4	2		8	2
<i>Cladium effusum</i> (saw grass).....	68	5	83	46		103	15
<i>Cladium mariscoides</i> (twig-rush).....		1	8	9		1	
<i>Scleria</i> sp. (nut rush).....						6	3
<i>Carex decomposita</i> (panicked sedge).....	1		10	2		2	21
<i>Carex lupuliformis</i> (hop sedge).....							8
<i>Carex</i> sp. (sedge).....	8	12	62	57	5	19	33
Araceæ.							
<i>Peltandra virginica</i> (arrow-arum).....							5
<i>Symplocarpus foetidus</i> (skunk cabbage).....							1
Lemnaceæ.							
<i>Spirodela polyrhiza</i> (big duckweed).....							99
<i>Lemna perpusilla</i> (minute duckweed).....							1
<i>Lemna minor</i> (small duckweed).....							1
<i>Lemna</i> sp. (unidentified duckweeds).....	17	3	44	14		15	185
Eriocaulaceæ.							
<i>Eriocaulon decangulare</i> (pipewort).....							1
<i>Eriocaulon</i> sp. (pipewort).....		1					
Pontederiaceæ.							
<i>Pontederia cordata</i> (pickerel weed).....	1		1			8	9
<i>Heteranthera dubia</i> (water star-grass).....				1			2
<i>Heteranthera</i> sp. (mud plantain).....						1	1
Juncaceæ.							
<i>Juncus</i> sp. (bog rush).....			2			2	
Liliaceæ.							
<i>Polygonatum biflorum</i> (hairy Solomon's-seal).....							1
<i>Smilax</i> sp. (greenbriar).....							2
Haemodoraceæ.							
<i>Gyrotheca tinctoria</i> (red-root).....							3
Piperaceæ.							
<i>Saururus cernuus</i> (lizard's-tail).....							15

TABLE I.—Items of vegetable food identified in the stomachs of the ducks treated in this bulletin and the number of stomachs in which found—Continued.

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
SUBKINGDOM SPERMATOPHYTA—Continued.							
Salicaceae.							
Salix sp. (willow), galls.....				1			
Salix sp. (willow), capsules.....	1						1
Myricaceae.							
Myrica cerifera (wax myrtle).....							6
Myrica californica (California myrtle).....						3	
Myrica sp. (unidentified myrtles).....	7	5	4	18		42	3
Juglandaceae.							
Hicoria aquatica (bitter pecan).....							76
Betulaceae.							
Carpinus caroliniana (hornbeam; blue beech).....							5
Betula sp. (birch).....			5				
Alnus sp. (alder).....			2			1	
Fagaceae.							
Fagus grandifolia (American beech).....							3
Quercus rubra (red oak).....							1
Quercus palustris (pin oak).....							5
Quercus nigra (water oak).....							2
Quercus marylandica (black-jack oak).....							2
Quercus lobata (valley oak).....							1
Quercus sp. (unidentified acorns).....							8
Urticaceae.							
Ulmus sp. (elm).....							1
Planera aquatica (water elm).....							66
Celtis sp. (hackberry).....	1						1
Morus rubra (red mulberry).....							1
Boehmeria cylindrica (false nettle).....							3
Boehmeria sp. (false nettle).....			2				
Polygonaceae.							
Rumex persicarioides (golden dock).....			1				
Rumex sp. (dock).....	2		4	2	2	7	7
Polygonum amphibium (water smartweed).....	3	11	34	27	3	23	24
Polygonum arifolium (prickly smartweed).....							1
Polygonum aviculare (knotweed).....	2	2	8			7	
Polygonum convolvulus (black bindweed).....	1	1	1			1	
Polygonum hydropiper (water pepper).....	2	2	12	10		5	8
Polygonum hydropiperoides (mild water pepper).....	2	1	10	31		29	24
Polygonum lapathifolium (dock-leaved smartweed).....	5	6	29	26	3	6	4
Polygonum opelousanum (smartweed).....	1		14	7		4	10
Polygonum pennsylvanicum (Pennsylvania smartweed).....	2		3	3		5	4
Polygonum persicaria (lady's-thumb).....	2	2	9	10	1	3	2
Polygonum portoricense (dense-flowered smartweed).....			3	1			
Polygonum punctatum (dotted smartweed).....			4			1	1
Polygonum sagittatum (arrow-leaved smartweed).....	2		7	11		10	8
Polygonum sp. (unidentified smartweeds).....			22	16	3	22	17

TABLE I.—Items of vegetable food identified in the stomachs of the ducks treated in this bulletin and the number of stomachs in which found—Continued.

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
SUBKINGDOM SPERMATOPHYTA —Continued.							
Chenopodiaceae:							
<i>Chenopodium album</i> (lamb's-quarters).....			3				
<i>Chenopodium</i> sp. (pigweed).....	1			1	1	5	
<i>Atriplex</i> sp. (saltbush).....		2	2			1	
<i>Salicornia ambigua</i> (glasswort; picklegrass)....	1	3	1			53	
Amaranthaceae.							
<i>Amaranthus retroflexus</i> (green amaranth).....			2				
<i>Amaranthus</i> sp. (pigweed).....	1		20	5	1	15	
Caryophyllaceae.							
<i>Spergula arvensis</i> (corn spurrey).....			2			2	
<i>Arenaria</i> sp.....			1				
Unidentified.....				1			
Portulacaceae.							
<i>Portulaca oleracea</i> (common purslane).....						1	
<i>Portulaca</i> sp. (purslane).....	2	2	3			1	
Ceratophyllaceae.							
<i>Ceratophyllum demersum</i> (coontail; hornwort)...	59	3	20	7		25	186
Nymphaeaceae.							
Unidentified.....						1	
<i>Nymphaea advena</i> (cowlily; spatter-dock).....							4
<i>Nymphaea microphylla</i> (small yellow pondlily) ..							5
<i>Nymphaea mexicana</i> (banana waterlily).....						1	
<i>Nymphaea</i> sp. (yellow pondlily).....		2	2			6	3
<i>Castalia odorata</i> (sweet-scented waterlily).....						1	3
<i>Castalia tuberosa</i> (white waterlily).....							4
<i>Castalia</i> sp. (waterlily).....	3	1	10	14		9	3
<i>Castalia</i> sp., tubers.....			1				
<i>Brasenia schreberi</i> (water shield).....	1	2	20	13		34	11
<i>Cabomba caroliniana</i> (Carolina water shield)....							2
Ranunculaceae.							
<i>Ranunculus delphinifolius</i> (yellow water-crow-foot).....			2	1	1		
<i>Ranunculus</i> sp. (crowfoot).....	5	8	8	6		17	13
Papaveraceae.....							
Cruciferae.							
Unidentified.....						1	
<i>Brassica</i> sp. (mustard).....			1				1
<i>Barbarea</i> sp. (winter cress).....			1				
Hamamelidaceae.							
<i>Liquidambar styraciflua</i> (sweet gum).....				7			5
Rosaceae.							
Unidentified.....						1	
<i>Crataegus</i> sp. (hawthorn).....			2	1		12	6
<i>Fragaria</i> sp. (strawberry).....				1			
<i>Rubus</i> sp. (bramble).....	1	2	15	15		43	4
<i>Rosa</i> sp. (rose).....						1	
Leguminosae.							
<i>Cassia marylandica</i> (American senna).....						1	
<i>Cassia</i> sp. (unidentified senna).....						7	
<i>Trifolium arvense</i> (rabbit's-foot clover).....			1				
<i>Trifolium</i> sp. (clover).....	1		6	3	1	1	

TABLE I.—Items of vegetable food identified in the stomachs of the ducks treated in this bulletin and the number of stomachs in which found—Continued.

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
SUBKINGDOM SPERMATOPHYTA —Continued.							
Leguminosae—Continued.							
<i>Melilotus</i> sp. (sweet clover).....		2		3			
<i>Medicago denticulata</i> (bur clover).....		1	1		2		
<i>Medicago</i> sp.....					1		
<i>Vicia</i> sp. (vetch).....						1	
<i>Vigna sinensis</i> (cow pea).....						2	
Unidentified.....			1				
Geraniaceae.							
<i>Geranium</i> sp. (cranesbill).....			1				
<i>Erodium</i> sp. (storksbill).....						1	
Euphorbiaceae.							
<i>Croton texensis</i>				1			
<i>Croton</i> sp. (spurge).....		1	1			2	16
<i>Euphorbia</i> sp.....			1				1
Empetraceae.							
<i>Empetrum nigrum</i> (crowberry).....			1				
Anacardiaceae.							
<i>Rhus glabra</i> (smooth sumach).....							1
<i>Rhus toxicodendron</i> (poison ivy).....	1		1				1
<i>Rhus laurina</i> (California sumach).....					1		
<i>Rhus</i> sp. (unidentified sumachs).....	25	1	1	2		1	24
Aquifoliaceae.							
<i>Ilex</i> sp. (holly).....	5	1	1	5		7	41
Rhamnaceae.							
<i>Berchemia scandens</i> (supple jack).....							13
<i>Rhamnus cathartica</i> (buckthorn).....							1
Vitaceae.							
<i>Vitis cordifolia</i> (frost grape).....							3
<i>Vitis</i> sp. (grapes).....	2		22	2		11	138
Malvaceae.							
Unidentified.....					2	3	
<i>Abutilon abutilon</i> (Indian mallow).....						1	
<i>Sida spinosa</i> (nail grass).....			1	2			
<i>Sida</i> sp. (nail grass).....						3	
<i>Malva</i> sp. (mallow).....				1		1	
<i>Kosteletzkya virginica</i>						1	
<i>Hibiscus</i> sp. (rose mallow).....				2		1	1
Hypericaceae.							
<i>Hypericum</i> sp. (St. John's-wort).....							1
Cactaceae.							
<i>Opuntia</i> sp. (prickly pear).....					5		
Lythraceae.							
<i>Decodon verticillatus</i> (swamp loosestrife; willow herb).....			1	1			2
Onagraceae.							
<i>Jussiaea</i> sp. (primrose willow).....				6			8
Haloragidaceae.							
<i>Myriophyllum verticillatum</i> (whorled milfoil).....		1					
<i>Myriophyllum</i> sp. (water milfoil).....	9	23	58	44	2	24	12
<i>Proserpinaca</i> sp. (mermaid weed).....	1		1	5		6	18
<i>Hippuris vulgaris</i> (bottle brush).....	6	18	16	8	3	12	2

TABLE I.—*Items of vegetable food identified in the stomachs of the ducks treated in this bulletin and the number of stomachs in which found*—Continued.

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
SUBKINGDOM SPERMATOPHYTA—Continued.							
Umbelliferae.							
<i>Apium</i> sp. (wild parsley).....			1				
<i>Hydrocotyle</i> sp. (water pennywort).....	3		19	12		3	44
<i>Centella asiatica</i> (marsh pennywort).....				2		7	
<i>Cicuta curtisii</i> (water hemlock).....						1	
<i>Cicuta</i> sp. (water hemlock).....		5				3	
Cornaceae.							
<i>Cornus amomum</i> (kinnikinnik).....							3
<i>Cornus asperifolia</i> (rough-leaved dogwood).....							3
<i>Cornus</i> sp. (dogwood).....	1	1	2				1
<i>Nyssa sylvatica</i> (sour gum).....							9
<i>Nyssa aquatica</i> (large tupelo).....							2
<i>Nyssa</i> sp. (tupelo).....						1	11
Ericaceae.							
<i>Gaultheria</i> sp. (wintergreen).....				2			
<i>Gaylussacia</i> sp. (huckleberry).....			2			1	
<i>Vaccinium</i> sp. (blueberry).....		1	1			7	1
Styracaceae.							
<i>Styrax grandifolia</i> (storax).....							1
<i>Styrax</i> sp. (storax).....							7
Oleaceae.							
<i>Fraxinus americana</i> (white ash).....							1
<i>Fraxinus</i> sp. (ash).....							1
<i>Adelia acuminata</i> (swamp privet).....							31
Gentianaceae.							
<i>Menyanthes trifoliata</i> (bog bean).....			2			2	
Asclepiadaceae.							
<i>Asclepias</i> sp. (milkweed).....		1				1	
Convolvulaceae.							
<i>Cuscuta</i> sp. (dodder).....	2	2	19	11		8	1
Boraginaceae.							
<i>Heliotropium indicum</i> (wild heliotrope).....	1	3	47	16	2	28	22
Verbenaceae.							
<i>Verbena hastata</i> (blue verbena).....			1				
<i>Verbena</i> sp. (verbena).....	1		3	11		1	1
<i>Lippia nodiflora</i> (fog-fruit).....						1	
<i>Lippia</i> sp. (fog-fruit).....		1	22	13		5	7
<i>Callicarpa americana</i> (French mulberry).....						1	
Labiatae.							
Unidentified.....						1	
<i>Trichostema</i> sp. (blue curls).....						1	
<i>Mentha</i> sp. (mint).....			2				
Solanaceae.							
<i>Solanum</i> sp. (night shade).....			5				
Scrophulariaceae.							
<i>Monniera rotundifolia</i> (water hyssop).....			5			1	
Plantaginaceae.							
<i>Plantago</i> sp. (plantain).....			5	1			

TABLE I.—*Items of vegetable food identified in the stomachs of the ducks treated in this bulletin and the number of stomachs in which found—Continued.*

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon-teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
SUBKINGDOM SPERMATOPHYTA—Continued.							
Rubiaceae.							
<i>Galium</i> sp. (cleavers).....	1	1	2	10	2	3	1
<i>Diodia virginiana</i> (buttonweed).....							6
<i>Diodia teres</i> (rough buttonweed).....				1		1	
<i>Cephalanthus occidentalis</i> (buttonbush).....	23	2	29	5		8	192
Caprifoliaceae.							
<i>Symphoricarpos</i> sp. (snowberry).....			2				1
<i>Sambucus</i> sp. (elder).....		1	5	1		32	
Compositae.							
Unidentified.....	2	1					1
<i>Ambrosia artemisifolia</i> (ragweed).....			1	3		1	
<i>Ambrosia trifida</i> (giant ragweed).....						2	2
<i>Ambrosia</i> sp. (ragweed).....			4	5		3	
<i>Xanthium spinosum</i> (cocklebur).....			1				
<i>Helianthus maximiliana</i> (sunflower).....			1				
<i>Helianthus</i> sp. (sunflower).....	1	1	1			4	
<i>Bidens</i> sp. (bur marigold).....	5	2	3	2		6	25
<i>Carduus</i> sp. (plumeless thistle).....	1		1			3	
<i>Taraxacum</i> sp. (dandelion).....				1			
<i>Lactuca</i> sp. (lettuce).....			2				

TABLE II.—*Items of animal food identified in the stomachs of the ducks treated in this bulletin and number of stomachs in which found.*

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon-teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
SUBKINGDOM PROTOZOA.							
Foraminifera.....			13			1	
SUBKINGDOM COELENTERATA.							
Hydrozoa (hydroids).....	2	2	3			13	
Acyonaria.....						1	
SUBKINGDOM MOLLUSCOIDA.							
Phylactolaemata (fresh-water Bryozoa).....	7		2			1	2
SUBKINGDOM ANNULATA.							
Nereidae.							
<i>Nereis</i> sp. (marine worms).....			3			5	
SUBKINGDOM ARTHROPODA.							
CLASS Crustacea (CRUSTACEANS).							
Unidentified.....	1	2	11	5		4	

TABLE II.—*Items of animal food identified in the stomachs of the ducks treated in this bulletin and number of stomachs in which found.*—Continued.

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
CLASS Crustacea—Continued.							
Order OSTRACODA.							
Unidentified ostracods (bivalved crustaceans).....	21	2	61	8	1	35	1
Cytheridae.							
<i>Cythere</i> sp.....						1	
Cyprididae.							
<i>Candona sigmoides</i>						1	
<i>Candona simpsoni</i>						1	
Order AMPHIPODA.							
Unidentified.....		2	11	4		17	5
Corophiidae.							
<i>Corophium cylindricum</i>			1				
<i>Corophium</i> sp.....			1				
Gammaridae.							
<i>Pseudalibrotus littoralis</i>		1					
<i>Gammarus fasciatus</i> (sand fleas).....						2	
<i>Gammarus locusta</i>				1			
<i>Gammarus</i> sp.....		4	13				
Orchestiidae.							
<i>Hyalella azteca</i>							1
<i>Hyalella knickerbockeri</i>				1			
<i>Hyalella dentata</i>			1	1		1	
Podoceridae.							
<i>Amphithoe longimana</i>		1					
Order COPEPODA.							
Unidentified copepods (water fleas).....			1				
Order ISOPODA.							
Unidentified.....			2			4	1
Oniscidae.							
Unidentified sowbugs.....	1					1	1
Asellidae.							
<i>Asellus</i> sp. (asel).....							1
<i>Mancasellus brachyurus</i> (asel).....							1
Order DECAPODA.							
Suborder MACRURA.							
Crangonidae.							
Unidentified shrimps.....						2	
<i>Crangonyx gracilis</i> (shrimp).....				1			
Astacidae.							
Unidentified crawfishes.....	2					4	2
<i>Cambarus propinquus</i>							1
<i>Cambarus</i> sp.....							1
Suborder BRACHYURA.							
Unidentified crabs.....	2		1	1		18	
Pilumnidae.							
<i>Hexapanopeus angustifrons</i>						10	
<i>Neopanope texana</i> (Say crab).....	1						

TABLE II.—*Items of animal food identified in the stomachs of the ducks treated in this bulletin and number of stomachs in which found—Continued.*

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined	417	255	653	319	41	790	413
CLASS Myriapoda.							
Unidentified centipedes			1				2
CLASS Insecta (INSECTS).							
Unidentified insect fragments, eggs, larvae, and pupae	9	13	52	14	1	23	24
Unidentified insect galls							5
Order THYSANURA.							
Unidentified							2
Superorder AMPHIBIOTICA.							
Unidentified damselflies or dragonflies and nymphs.	1	1		3	1	5	32
Order ZYGOPTERA (Damselflies).							
Unidentified damselflies and nymphs	2		2			2	1
Agrionidae.							
<i>Nehalennia</i> sp.			1				
<i>Enallagma</i> sp.				2		1	
Order ANISOPTERA (Dragonflies).							
Unidentified dragonflies and nymphs	2		17	22	2	21	41
Aeschnidae, nymphs			1			3	1
Libellulidae.							
Unidentified nymphs			1				2
<i>Somatochlora</i> sp.						1	
<i>Sympetrum</i> sp.			1				
<i>Cordulia</i> sp.						2	
Order AGNATHA (Mayflies).							
Unidentified Mayfly nymphs	1					1	2
Order PLECOPTERA (Stoneflies).							
Unidentified stonefly larvae			3				
Order ISOPTERA (Termites).							
<i>Claotermes castaneus</i> (termite)							1
Order ORTHOPTERA (Grasshoppers, etc.).							
Unidentified grasshoppers and their eggs			4	1		5	2
Acridiidae.							
Unidentified		1				1	
<i>Melanoplus</i> sp.							1
Tettiginae (grouse locusts).							
Unidentified							7
<i>Tettigidea</i> sp.							1
Locustidae (green grasshoppers).							
Unidentified							2
<i>Orchelimum</i> sp.							11
Gryllidae (crickets).							
<i>Nemobius</i> sp.		2					1

TABLE II.—*Items of animal food identified in the stomachs of the ducks treated in this bulletin and number of stomachs in which found—Continued.*

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Bue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
CLASS Insecta —Continued.							
Order MALLOPHAGA (Bird Lice).							
Unidentified.....			1				
Order HETEROPTERA (True Bugs).							
Unidentified bugs.....			6	2		3	15
Corixidae (water boatmen).							
Unidentified species.....	25	9				33	15
<i>Corixa</i> sp.....			32	43	11		
Belostomatidae (giant water bugs).							
<i>Belostoma</i> sp.....				1		1	37
Nepidae (water scorpions).							
<i>Ranatra fusca</i>							2
Naucoridae (creeping water bugs).							
<i>Pelocoris femoratus</i>				2		2	
<i>Pelocoris</i> sp.....	6			13		7	43
Notonectidae (back-swimmers).							
<i>Notonecta</i> sp.....				1			2
<i>Buenoa</i> sp.....							1
<i>Plea striola</i>			4	11			17
Saldidae (shorebugs).							
<i>Salda</i> sp.....	1						
Veliidae (broad-shouldered water striders).							
<i>Microvelia</i> sp.....							7
<i>Velia australis</i>							4
Gerridae (water striders).							
<i>Gerris marginata</i>							1
<i>Gerris</i> sp.....	4		4	2			29
Hydrometridae.							
<i>Hydrometra</i> sp.....							4
Miridae.							
Unidentified.....		1					
<i>Lygus pratensis</i>							1
Mesoveliidae.							
<i>Mesovelia mulsanti</i>				2			6
Hebridae.							
<i>Hebrus</i> sp.....							1
Reduviidae (assassin bugs)							2
Coreidae.							
<i>Darmistus</i> sp.....							1
Pentatomidae (stink bugs).							
Unidentified.....	1						7
<i>Menecles incertus</i>				1			
<i>Euschistus variolarius</i>							1
<i>Euschistus</i> sp.....							2
Corimelaenidae.							
<i>Corimelaena nitiduloides</i>				1			

TABLE II.—*Items of animal food identified in the stomachs of the ducks treated in this bulletin and number of stomachs in which found—Continued.*

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
CLASS Insecta —Continued.							
Order HOMOPTERA .							
Cicadellidae.							
<i>Draeculacephala mollipes</i>							1
Fulgoridae.							
Unidentified.....				1			
<i>Scolops</i> sp.....	1						
<i>Dicranotropis</i> sp.....							1
Jassidae (leafhoppers).....			1	1			
Aphididae (plant lice).							
<i>Rhopalosiphum nymphaeae</i>							4
Order MEGALOPTERA (Fishflies).							
Unidentified larvae.....							1
Order NEUROPTERA .							
Unidentified.....			1				
Sialidae (dobson, etc.).....			1	1			
Order PHYRYGANOIDEA (Caddisflies).							
Unidentified larvae and cases.....	9	7	46	31	1	34	4
Phryganeidae.							
<i>Phryganea improba</i>							1
Limnephilidae.							
<i>Stenophylax</i> sp.....							1
Sericostomatidae.							
<i>Brachycentrus incanus</i>							1
Hydropsychidae.							
<i>Hydropsyche</i> sp.....							1
Order LEPIDOPTERA (Butterflies and Moths).							
Hemileucidae.							
<i>Hemileuca maia</i>							1
Arctidae.....							1
Noctuidae.....							1
Geometridae, pupa.....							1
Pyralidae.....							2
Tineidae, cocoon.....				3			
Unidentified moths.....			1				2
Unidentified pupae.....							6
Unidentified caterpillars.....	1	1					13
Order COLEOPTERA (Beetles).							
Unidentified fragments and larvae.....	18	16	40	50	21	40	62
Cicindelidae (tiger beetles).....							1
Carabidae (ground beetles).							
Unidentified.....	2		6	3		3	6
<i>Carabus vinctus</i>							1
<i>Scarites substriatus</i>							1
<i>Scarites</i> sp.....						1	

TABLE II.—Items of animal food identified in the stomachs of the ducks treated in this bulletin and number of stomachs in which found—Continued.

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
CLASS Insecta —Continued.							
Order COLEOPTERA —Continued.							
Carabidae (ground beetles)—Continued.							
<i>Aspidoglossa subangulata</i>				1			
<i>Bembidium intermedium</i>				1			
<i>Bembidium insulatum</i>	1						
<i>Bembidium</i> sp.....	1					1	
<i>Loxandrus velox</i>						1	
<i>Platynus</i> sp.....				1			1
<i>Chlaenius</i> sp.....				1		2	
<i>Anomoglossus pusillus</i>							1
<i>Harpalus caliginosus</i>							1
<i>Selenophorus</i> sp.....				1			
<i>Stenolophus conjunctus</i>						1	
<i>Anisodactylus dulcicollis</i>				1			
<i>Anisodactylus rusticus</i>				1			
Halipidae (crawling water beetles).							
Unidentified.....			4			1	
<i>Halipus triopsis</i>							2
<i>Halipus unicolor</i>				1			
<i>Halipus</i> sp.....				2		1	1
<i>Cnemidodus edentulus</i>						1	
<i>Cnemidodus pedunculatus</i>							1
<i>Cnemidodus</i> sp.....							1
<i>Peltodytes simplex</i>				1			
<i>Peltodytes callosus</i>					1		
<i>Peltodytes</i> sp.....				4			
Dytiscidae (predacious diving beetles).							
Unidentified adults and larvae.....	3	2	22	8	2	4	9
<i>Colpius inflatus</i>				3		3	1
<i>Canthydrus bicolor</i>				1		1	
<i>Canthydrus puncticollis</i>						1	
<i>Hydrocanthus iricolor</i>				1		2	
<i>Hydrovatus compressus</i>						1	
<i>Hydrovatus</i> sp.....							1
<i>Bidessus affinis</i>			1	2			
<i>Bidessus obscurillus</i>					1		
<i>Bidessus flavicollis</i>			1	1			
<i>Bidessus</i> sp.....				2		1	
<i>Coelambus acaroides</i>							1
<i>Coelambus inaequalis</i>						1	
<i>Coelambus punctatus</i>						1	
<i>Coelambus turbidus</i>				1			
<i>Coelambus</i> sp.....					2	1	1
<i>Hydroporus</i> sp.....				1			
<i>Coptotomus interrogatus</i>				1			
<i>Coptotomus</i> sp.....							2
<i>Agabus</i> sp.....				1		1	
<i>Laccophilus decipiens</i>			1		1		

TABLE II.—Items of animal food identified in the stomachs of the ducks treated in this bulletin and number of stomachs in which found—Continued.

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
CLASS <i>Insecta</i> —Continued.							
Order <i>COLEOPTERA</i> —Continued.							
Gyrinidae (whirligig beetles).							
Unidentified							3
<i>Gyrinus</i> sp.				1			3
<i>Dineutes</i> sp.							3
Hydrophilidae (water scavenger beetles).							
Unidentified beetles and larvae	3		5	11	1	16	8
Unidentified egg-cases							3
<i>Hydrophilus californicus</i>					2		
<i>Hydrophilus</i> sp.						2	2
<i>Tropisternus</i> sp.							7
<i>Helophorus</i> sp.				3	2		
<i>Hydrocharis obtusatus</i>						1	
<i>Berosus pantherinus</i>				2			
<i>Berosus peregrinus</i>						1	
<i>Berosus striatus</i>						1	
<i>Berosus</i> sp.	4	7	7	6	1	8	4
<i>Philhydrus perplexus</i>						1	
<i>Philhydrus nebulosus</i>							2
<i>Philhydrus</i> sp.				1			2
<i>Hydrobius</i> sp.	1						
<i>Cercyon</i> sp.		1					
Staphylinidae (rove beetles)	1	1	2			2	2
Coccinellidae (ladybugs).							
Unidentified	1						
<i>Megilla maculata</i>	1						
<i>Hippodamia</i> sp.							1
Cucujidae (flat bark beetles).							
<i>Silvanus surinamensis</i>						1	
Dermestidae (larder beetles).							
Unidentified		1					
<i>Dermestes lardarius</i>		1					
Histeridae.							
<i>Hister</i> sp.				1			
Nitidulidae.							
<i>Stelidota geminata</i>							1
Byrrhidae	1			1			
Parnidae.							
<i>Elmis vittatus</i>			1				
Heteroceridae.							
<i>Heterocerus</i> sp.				2			
Elatерidae						1	1
Lucanidae.							
<i>Passalus cornutus</i>							2
Scarabaeidae (leaf chafers).							
Unidentified			1			2	11
<i>Onthophagus hecate</i>				1			
<i>Aphodius iniquinatus</i>		1				1	1
<i>Aphodius</i> sp.	1	1	2	1			1
<i>Phyllophaga</i> sp. (May beetles).....				1			2
<i>Dyscinetus trachypygus</i>							1

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Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
CLASS Insecta—Continued.							
Order COLEOPTERA—Continued.							
Cerambycidae (long-horned beetles).							
Unidentified.....							1
<i>Leptostylus aculiferus</i>							1
<i>Liopus</i> sp.....							1
Chrysomelidae (leaf beetles).							
Unidentified.....	1	2		2		2	
<i>Donacia cincticornis</i>							2
<i>Donacia subtilis</i>							2
<i>Donacia proxima</i>							1
<i>Donacia</i> sp.....	1	1	2	2	1	1	11
<i>Xanthonia decemnotata</i>	1						
<i>Prasocuris phellandrii</i>				1			
<i>Ceratoma trifurcata</i>							1
<i>Luperodes meraca</i>	1						
<i>Galerucella</i> sp.....	2					1	
<i>Phyllotreta pusilla</i>	1						
<i>Phyllotreta</i> sp.....				1			
Tenebrionidae.....	1						
Melandryidae.							
<i>Synchroa punctata</i>							1
Anthicidae (flower beetles).							
<i>Anthicus haldemani</i>	1						
<i>Anthicus</i> sp.....	1						
Meloidae (blister beetles).....	1						
Suborder RHYNCHOPHORA (Weevils).							
Unidentified adults.....	12	1	17	8	2	14	12
Unidentified larvae.....							2
Curculionidae (snout beetles).							
Unidentified.....				1	2		
Otiorynchinae.....						1	
<i>Hypera punctata</i>							3
Erirhinini.....						2	
<i>Lixellus filiformis</i>				1			
<i>Bagous</i> sp.....	1						
<i>Endalus</i> sp.....						1	
<i>Sphenophorus aequalis</i>				1			
<i>Sphenophorus ochreus</i>		1					
<i>Sphenophorus</i> sp.....				3		2	1
<i>Calandra</i> sp.....			1				
Order DIPTERA (Flies).							
Unidentified adults, larvae, and pupae.....	13	1	14	8	2	10	4
Tipulidae (crane flies).							
Unidentified adults, larvae, and pupae.....	1	3	5			3	
Ctenophorinae, larvae.....							1

TABLE II.—*Items of animal food identified in the stomachs of the ducks treated in this bulletin and number of stomachs in which found—Continued.*

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
CLASS Insecta —Continued.							
Order DIPTERA —Continued.							
Chironomidae (midges).							
Unidentified adults, larvae, and pupae.....	10	12	61	10	2	31	2
<i>Chironomus</i> sp.....							1
<i>Ceratopogon</i> sp.....				1			
Simuliidae.							
<i>Simulium</i> sp.....			1	1			
Stratiomyidae (soldierflies).							
Unidentified larvae.....			3	11	3	7	31
<i>Odontomyia</i> sp.....	2					1	2
<i>Nemotelus</i> sp.....							1
Tabanidae (horseflies), larvae.....	1		1			2	
Syrphidae (flowerflies).							
Unidentified larvae and pupae.....				4	1		1
<i>Syrphus</i> sp.....							1
Anthomyiidae, adults.....				1			
Asilidae (robberflies), adults.....			1				
Dolichopodidae (long-footed flies), adults.....			1				
Muscidae.							
<i>Lucilia</i> sp.....		1					
Borboridae.....	3						
Ephydriidae, (brine flies), larvae and pupae.....	8	9	21	1	3	15	
Scatophagidae.							
<i>Hydromyza confluens</i>							1
Order HYMENOPTERA (Ants, Bees, and Wasps).							
Unidentified adults and cocoons.....	3		9	1	2	6	7
Tenthredinoidea (saw flies), cocoon.....							1
ICHNEUMONOIDEA (Parasitic wasps).							
Vipionidae.							
<i>Protopanteles</i> sp.....							1
Braconidae.							
<i>Bassus</i> sp.....							1
<i>Meteorus</i> sp.....							1
Ichneumonidae.							
Unidentified.....							1
<i>Amblyteles</i> sp.....				1			1
<i>Lissonota</i> sp.....							1
<i>Metopius</i> sp.....	1						
<i>Paniscus</i> sp.....						1	
<i>Phaeogenes</i> sp.....					1		1
CHALCIDOIDEA.							
Chalcididae.							
<i>Chalcis</i> sp.....							1
<i>Spilochalcis</i> sp.....	1						
SEEPHOIDEA.							
Unidentified.....							2
Scelionidae.							
<i>Hadronotus</i> sp.....	1						

TABLE II.—Items of animal food identified in the stomachs of the ducks treated in this bulletin and number of stomachs in which found—Continued.

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
CLASS Insecta —Continued.							
Order HYMENOPTERA —Continued.							
FORMICOIDEA (Ants).							
Formicidae.							
Unidentified.....	8	2	17	18	1	12	12
<i>Ponera</i> sp.....							2
<i>Monomorium</i> sp.....							1
<i>Solenopsis</i> sp.....							1
<i>Crematogaster</i> sp.....							18
<i>Myrmica rubra scabrinodis</i>							1
<i>Formica</i> sp.....							2
<i>Camponotus herculeanus pennsylvanicus</i>							15
<i>Camponotus</i> sp.....							4
SPHECOIDEA.							
Sphecidae.							
<i>Diploplectron</i> sp.....		1					
VESPOIDEA (Wasps).							
Unidentified.....			1			1	3
Vespidae.							
<i>Polistes annularis</i>							1
APOIDEA (Bees).							
Halictidae.							
<i>Halictus</i> (<i>Chloralictus</i>).....							1
CLASS Arachnida .							
Order PSEUDOSCORPIONIDA .							
Unidentified.....				1			
Order ARANEIDA (Spiders).							
Unidentified.....	3	1	3	3			74
Argiopidae (orb-weavers).							
<i>Tetragnatha extensa</i>							1
Order ACARIDA (Mites).							
Unidentified.....			2				
Hydrachnidae (water mites).....	3	1	18	22	2	11	5
SUBKINGDOM MOLLUSCA (MOLLUSKS).							
Unidentified.....	1	2	90	106	15	117	2
CLASS Pelecypoda (BIVALVES).							
Unidentified.....	3	4	3	2	2	73	8
Mytilidae.							
<i>Mytilus edulis</i>						1	
Veneridae.							
<i>Anomalocardia cuneimeris</i>						16	
<i>Anomalocardia</i> sp.....						1	
<i>Gemma gemma</i>						1	
Cyrenidae.							
<i>Musculium</i> sp.....							1
<i>Sphaerium striatinum</i>		1					
<i>Sphaerium stamineum</i>		1					

TABLE II.—*Items of animal food identified in the stomachs of the ducks treated in this bulletin and number of stomachs in which found—Continued.*

Kind of food.	Gad-wall.	Bald-pate.	Green-winged teal.	Blue-winged teal.	Cinnamon teal.	Pin-tail.	Wood duck.
Total number of stomachs examined.....	417	255	653	319	41	790	413
CLASS Pelecypoda —Continued.							
Cyrenidae—Continued.							
<i>Sphacrium</i> sp.....				3			
<i>Pisidium occidentale</i>						1	
<i>Pisidium</i> sp.....				2			
Tellinidae.							
<i>Tellina</i> sp.....						1	
<i>Macoma</i> sp.....						1	
<i>Angulus</i> sp.....						1	
Myidae.							
<i>Sphaenia ovoides</i>						3	
CLASS Gastropoda (UNIVALVES).							
Unidentified.....	5	24				71	9
Hydrobiidae.							
<i>Bythinella monroensis</i>						1	
<i>Bythinella</i> sp.....						2	
<i>Hydrobia</i> sp.....						2	
Acmacidae.							
<i>Acmaea testudinalis</i>						1	
Tornatinidae.							
<i>Tornatina canaliculata</i>						5	
Pleurotomidae.							
<i>Mangilia plicosa</i>						7	
Amnicolidae.							
<i>Amnicola coronata</i>						1	
<i>Amnicola porata</i>				2			
<i>Amnicola depressa</i>							1
<i>Amnicola cincinnatensis</i>		1					
<i>Amnicola</i> sp.....				3		1	
Physidae.							
<i>Physa heterostropha</i>			3	2		1	
<i>Physa gyrina</i>				1			
<i>Physa</i> sp.....	1			3		3	1
Lymnaeidae.							
<i>Lymnaea columella</i>				2			
<i>Lymnaea desidiosa</i>				1			
<i>Lymnaea palustris</i>				1			
<i>Lymnaea</i> sp.....						1	
<i>Planorbis bicarinata</i>				1			
<i>Planorbis duryi</i>				1			
<i>Planorbis glabratus</i>				2			
<i>Planorbis parvus</i>					4	3	
<i>Planorbis trivoltis</i>				4		1	
<i>Planorbis</i> sp.....	2		1	1			3
<i>Pompholyx effusa</i>						1	
Nassidae.							
<i>Nassa acuta</i>						2	
<i>Nassa vibex</i>						4	
<i>Ilyanassa obsoleta</i>						2	

TABLE II.—*Items of animal food identified in the stomachs of the ducks treated in this bulletin and number of stomachs in which found—Continued.*

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Total number of stomachs examined.....	417	255	653	319	41	790	413
CLASS Gastropoda —Continued.							
Columbellidae.							
<i>Anachis avara</i>						5	
<i>Anachis obesa</i>						12	
<i>Astiris lunata</i>						13	
Turbonillidae.							
<i>Turbonilla</i> sp.....						1	
Pyramidellidae.							
<i>Odostomia bisuturalis</i>						12	
<i>Odostomia</i> sp.....						10	
Auriculidae.							
<i>Melampus borealis</i>	1						
Olividae.							
<i>Olivella mutica</i>		1					
Littorinidae.							
<i>Littorina rudis</i>						1	
<i>Littorina irrorata</i>	1						
Cerithiidae.							
<i>Bittium nigrum</i>						3	
<i>Bittium varium</i>						1	
<i>Bittium</i> sp.....						5	
<i>Diaostomia varia</i>						11	
<i>Cerithium</i> sp.....						4	
<i>Cerithidea tenuis</i>						8	
Rissoidae.							
<i>Hydrobia californica</i>		2					
<i>Bithinella texana</i>	2						
<i>Bithinella</i> sp.....							1
<i>Fluminicola nuttalliana</i>						1	
<i>Pyrgulopsis spinosus</i>	1						
Assimineidae.							
<i>Assiminea affinis</i>						1	
Valvatidae.							
<i>Valvata virens</i>						1	
<i>Valvata tricarinata</i>		1		1			
Neritidae.							
<i>Neritina reclivata</i>			2			11	
<i>Neritina virginea</i>	25		3			40	
<i>Neritina</i> sp.....	1					7	
SUBKINGDOM CHORDATA (VERTEBRATES).							
CLASS Pisces (FISHES).							
Unidentified, teeth, scales, etc.....	12	2	3	3		15	5
Poeciliidae.							
<i>Fundulus</i> sp.....				2		1	
CLASS Amphibia (FROGS, TOADS, AND SALAMANDERS).							
Ranidae (frogs).							
Unidentified.....							2
<i>Rana</i> sp.....						1	

**PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING
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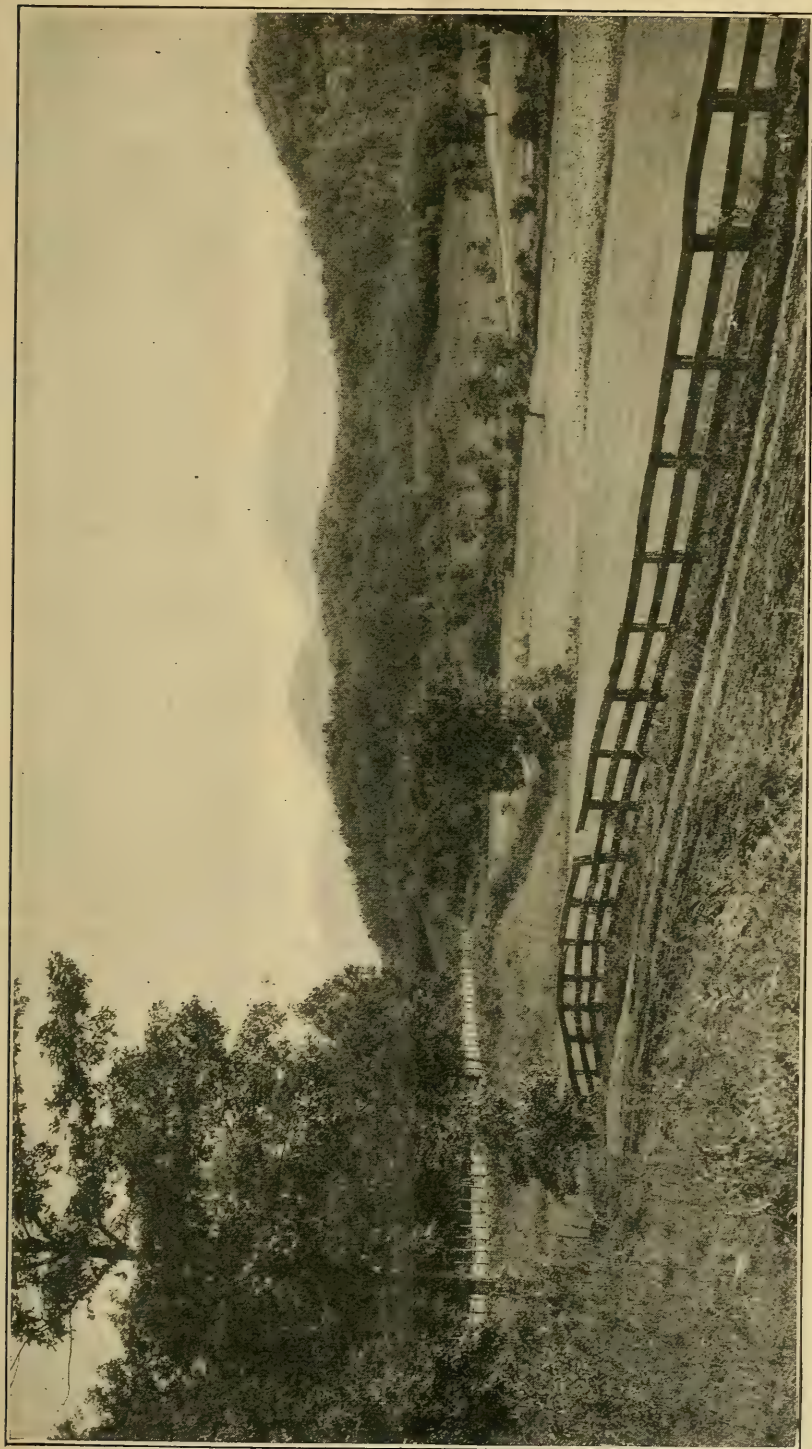
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The home forest.

FORESTRY LESSONS ON HOME WOODLANDS.

By WILBUR R. MATTOON, *Extension Specialist in Forestry, Forest Service*, and
ALVIN DILLE, *Specialist in Agricultural Education, States Relations Service*.

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INTRODUCTION.

The right handling of the home forest has come to be a matter of recognized importance in farm management. Farming touches forestry at a number of different points. The farm requires timber for the building and repair of houses, barns, sheds, fences, and telephone lines. It needs more or less wood for fuel, and it should have some woodland also for protecting the soil against erosion on steep slopes, for shelter for growing crops and live stock against the hot, dry winds of midsummer, the cold winds of winter, and likewise for the comfort of man, and the home of game animals.

A farm without some woods is less attractive as a place to live and usually less valuable than one with at least a little woodland and some forest trees scattered about. Thus woodlands have a place both in the management of the farm and in the development of the community.

The lessons which follow present the subject of farm forestry from the standpoint of the important local kinds of forest trees and their uses, the proper location of woodlands on the farm, their economic value to the farm, the different farm timber products, measuring and marketing timber, utilizing timber rightly on the farm, protecting and improving woodlands, and planting young timber. A knowledge of farm forestry, applied along simple lines, should make farm-

ing more profitable. These lessons have been prepared to give to the organized school work in elementary agriculture additional impetus in forestry, to provide material for instruction that is within the range of elementary pupils, and to furnish a topic for home projects that may be worked out profitably to every community and with real educational value to the pupils themselves.

SOURCES OF INFORMATION.

Practically all the subject matter for class use and instructions for home projects will be found in bulletins available, either free or at a small cost. Almost every State agricultural college has published one or more bulletins on some phase of forestry, and in most instances these may be had for the asking. Address the dean of the agricultural college.

The Farmers' Bulletins of the United States Department of Agriculture referred to in this bulletin will cover many of the topics to be studied. Bulletins in this list will be sent free, so long as the supply lasts, to any resident of the United States, upon application to his Senator, Representative, or Delegate in Congress, or to the Chief of the Division of Publications, U. S. Department of Agriculture, Washington, D. C. Because of the limited supply, applicants are urged to select only a few numbers, choosing those which are of special interest, and ordering but one copy of each. When the free supply has been exhausted, a number are yet for sale by the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents each. Other publications of this department are also for sale by the Superintendent of Documents, but these are more often technical bulletins and of interest to those only who wish to specialize in the subject.

Frequently revised classified lists of department publications on different phases of agriculture, one of which is on the subject of forestry, are issued by the Division of Agricultural Instruction, States Relations Service, U. S. Department of Agriculture, for teachers' use. The teacher will find that a number of the textbooks on forestry are suited to her needs, and that some of the elementary textbooks may be used by the pupils.

In addition to the Farmers' Bulletins and other Department Bulletins, the Forest Service issues a number of circulars on various phases of forestry which may be obtained directly from that division.

THE SURVEY.

One of the means by which the teacher may become informed about the forestry interests of the district is a woodland survey. The pupils may assist in obtaining this information, but a first-hand knowledge obtained by the teacher will be a valuable aid.

This survey should include the kind of woodland, whether hardwood, conifer, or mixed type, the important species of trees in the forest stand, in respect to their abundance and their use and commercial value, the leading rough timber products that have been sold, and the prices received in the woods or shipping point. This information may be collected and tabulated.

A map of the district may be procured, or, if not available, one can be drawn on a large sheet by the pupils. On this map the homes and farms of the pupils are to be located. Place signs, emblems, or colored bits of paper to represent various facts from your tabulations; for example, colored circles to represent young, middle age, or mature woodland, squares to represent timber products sold, etc. Additional facts may be placed on this map, taking especial note of the acreage per farm, interest in taking care of standing timber, etc.

ILLUSTRATIVE MATERIAL.

Construct a chart showing the relation in size of crown and trunk of a typical tree growing in the open (limby) and a tree in a close stand (long, smooth trunk). Illustrate by a diagram the maximum wood production per acre and quality production of good timber, by a crowded stand of trees and a thinned stand formerly containing more trees per acre.

Make drawings of the cross section of a tree trunk showing how the tree increases by a new ring of growth each year. Collect leaf specimens of the trees of the district and mount same on cardboard after pressing and drying them. Collect samples of the wood of the trees of the locality of approximately uniform size and mount them on boards, or hang them in frames or racks especially constructed.

If possible, obtain like specimens of the woods of other localities. These samples may be classified and mounted into groups such as hardwoods and softwoods, or oaks, maples, pines, etc. At least a small collection of such woods should be a part of the equipment of every school. Charts showing the relative importance and uses of the most abundant woods should be made.

Write to the Division of Agricultural Instruction, States Relations Service, U. S. Department of Agriculture, Washington, D. C., for list of lantern-slide sets with lecture syllabi on the different phases of forestry. These sets of slides are loaned to teachers free of charge.

THE HOME PROJECT.

It is agreed by teachers of agriculture that instruction in that subject should follow certain definite lines: (1) It should be seasonal. (2) It should be local in its interests and development. (3) It should meet the interests of the pupils. (4) It should be practical.

The home-project plan affords the best means of meeting these conditions, especially the practical side. The pupil is working out for himself the principles and theories taught in the classroom.

The term "home project," applied to instruction in elementary and secondary agriculture, includes each of the following requisites: (1) There must be a plant for work at home covering a season more or less extended. (2) It must be a part of the instruction in agriculture of the school. (3) There must be a problem more or less new to the pupil. (4) The parents and pupil should agree with the teacher on the plan. (5) Some competent person must supervise the home work. (6) Detailed records of time, method, cost, and income must be honestly kept. (7) A written report based on the record must be submitted to the teacher. This report may be in the form of a booklet.

Type of forestry project.—A project in forestry must of necessity be of a much different type than a project in farm crops or animal production. The slow growth of forest trees and other factors involved make it a project covering more than one season. However, forest projects can be conducted and made of much value to the student and community. Among the forestry projects that can be carried out, the following are suggested: The renovation of a farm woodland, the replanting of a woodland and subsequent care of the young trees, the planting of forest trees on some eroding lands or other waste ground on the farm, mapping and finding area of a forest tract, cutting and marketing farm forest products, giving especial attention to the proper cutting of trees and to the removal of the parts of the trees not marketed, a study and survey of forest fires, insect enemies, and the diseases of the common forest trees.

Lesson I. FOREST TREES AND FOREST TYPES.

Problem.—To learn to know at sight the chief forest trees of the locality.

Sources of information.—Bulletins of the State colleges of agriculture and State foresters on forest trees; Forestry Bulletin 17; forest tree key and description of 100 important forest trees on pages 40-48 of Supplement. The Forest Service, U. S. Department of Agriculture, Washington, D. C., is ready to identify leaves, fruit, buds, and wood that puzzle the young forester.

Illustrative material.—The best illustrative material for this lesson is to be found in the woods, where the trees may be seen and their characteristics studied. In case this can not be done, pictures of typical trees may be used. Blackboard sketches showing the form of different trees are easily made and should be used in this lesson.

Topics of study.—Getting acquainted with the important kinds of forest trees in your locality. Their various common names and other

names. A few trees are known widely by the same common name, but many are called by different names in various sections of the country. The importance of botanical names for certain identification. Distinguishing the different kinds or species of trees by some well-marked characteristics of leaf, bark, fruit, seed, buds, or twig arrangement.

Conifers: Trees bearing cones, such as the pines, spruces, firs, hemlocks, cedars, junipers, tamarack, and cypress. How does bald cypress differ from the others? Distinguishing characteristics of each group or genus, and something about its different members or species, particularly those that occur locally.

Hardwoods: Trees, most of which have wood harder than that of the conifers and broad leaves which are deciduous, or are shed in the fall. Kinds of hardwood trees which are evergreen. Group the hardwood trees into general groups, such as the oaks, maples, elms, and others, and identify as many different species of each as possible.

Kinds of trees which are associated together in different forest types, such as (*a*) ridge type, (*b*) slope or cove type, (*c*) bottomland type, and (*d*) swamp type. What trees locally are associated to make (*a*) coniferous forest type, (*b*) pure hardwood type, and (*c*) mixed hardwood and conifer type.

Practical exercises.—Gathering leaves and fruit of the important local forest trees; press in wrapping paper, folded and labeled with place and date.

Studying the shape and size of leaves; trace a leaf of each of the important kinds of trees, and label with name, place where found, and date.

Grouping trees by kinds of fruit borne—nuts, keys, berries, cones, etc.

Collect samples of winter buds from leading kinds of trees, labeling with name of tree, place of collection, and date.

Study of winter buds, with drawings of buds and twig arrangement.

Collect tree blossoms from red and silver maples, willows, catalpa, elm, oak, dogwood, tulip poplar, basswood, buckeye, and magnolia.

*Field study.*¹—Now to the woods, that may come into personal touch with the forest trees of your own neighborhood.

Leaves: The leaf is the trade-mark of the trees. Gather the leaves, study and compare them to gain a first knowledge of the trees as individuals, then as groups. The tulip poplar writes its name plainly upon its square-cut leaf, but the boxelder has a leaf somewhat resembling the ash, though its seed is similar to the maple key. Wherein does the ash leaf differ from that of the locust or the

¹ The sections on field study in Lessons I and III were contributed by Miss Lucy Kellerhouse, of the Forest Service.

hickory? The oaks are divided into the red and the white oaks. What is a typical leaf of each class?

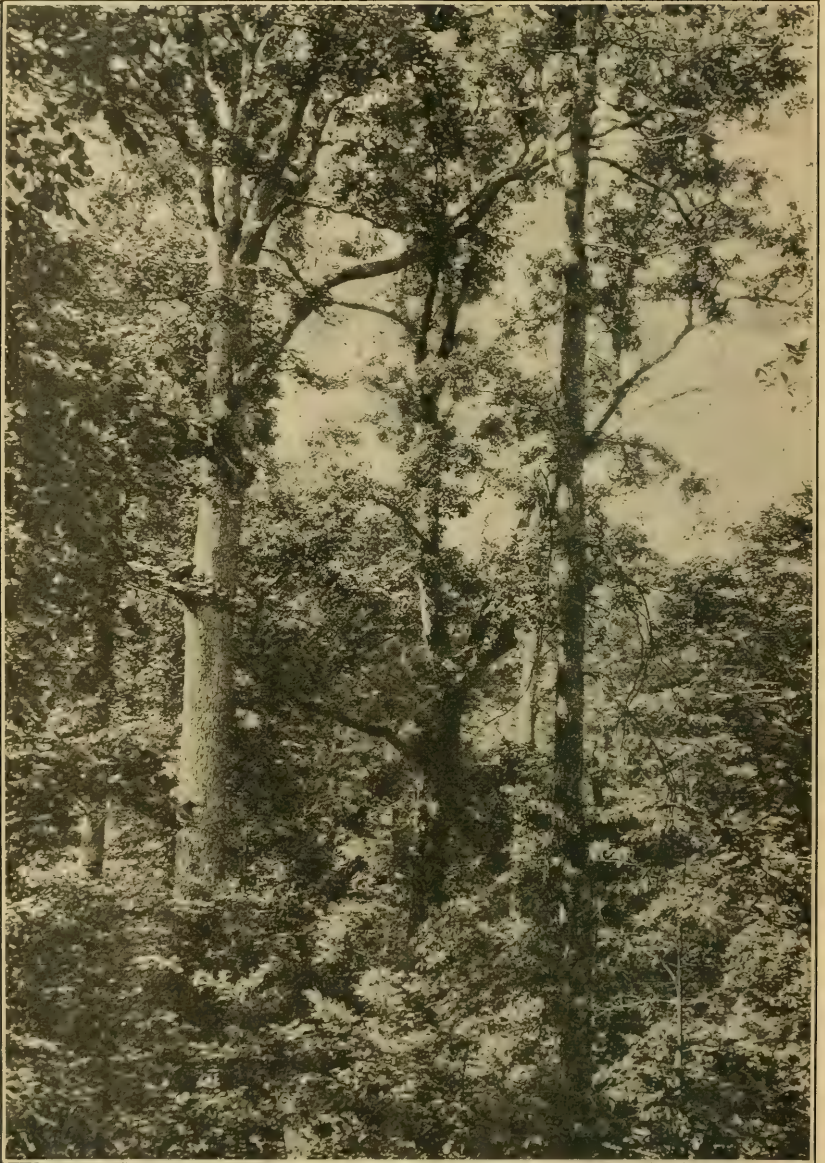


FIG. 1.—White oak, a woodland tree of wide distribution and high value, representative of the pure hardwood type.

You will probably begin this study in the autumn, so before the leaves fall and your memory of them fails, press and either mount them or place in paper folders, and label with name, place where found, and date.

If the black gum is now reddening the red gum will soon begin to burn, and presently all the woods will seem as if on fire. The autumn colors will help to identify your trees and beautify your herbarium. A few of the broadleaf trees and all the conifers save one are evergreen.

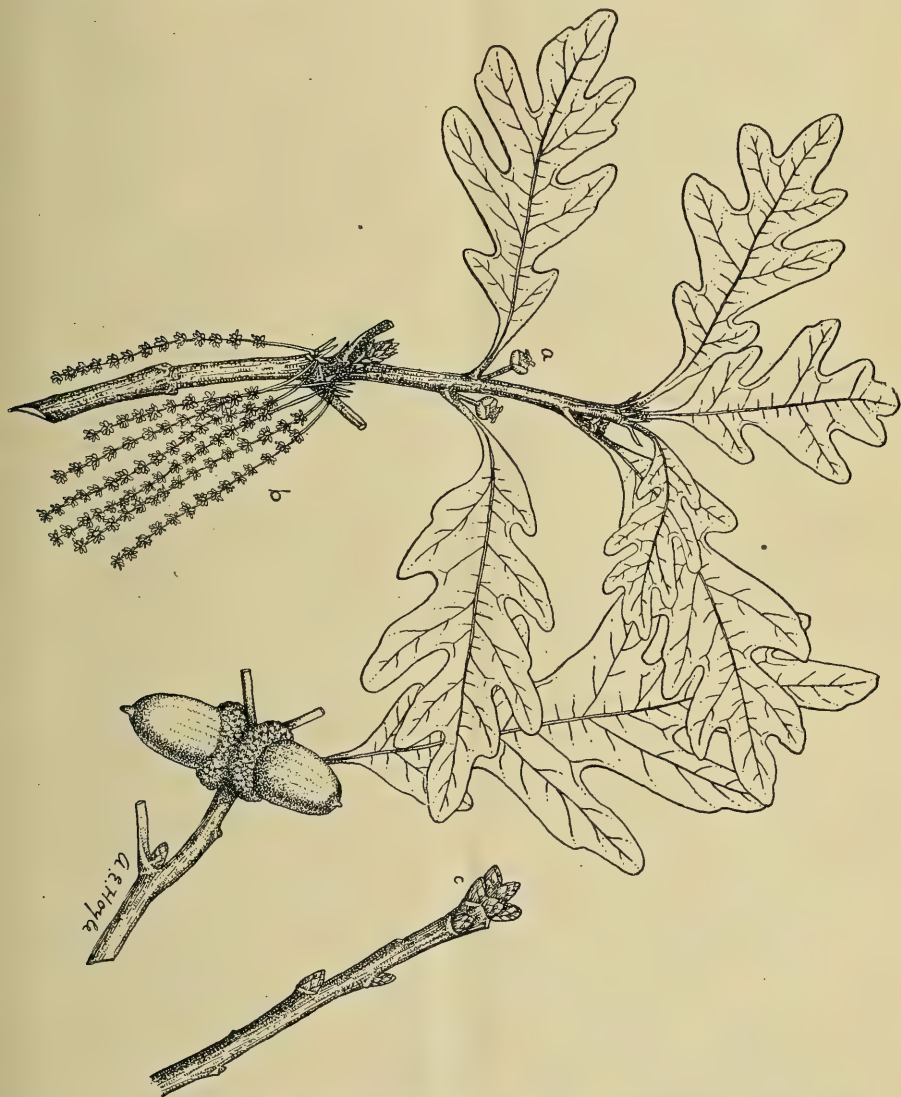


FIG. 2.—White oak leaf, flower, fruit, and winter bud: *a*, Pistillate or female flower; *b*, staminate or male flower; *c*, winter bud.

Separate the conifers into the pines, spruces, cedars, or other cone-bearers of your woods, and divide into as many species as you find. Draw a diagram, and under the two heads, broadleaf trees and conifers, group the trees that you identify, with a short description of each.

Fruit: While you are gathering leaves, bring in the fruit, or seed, that you find—the pulpy fruit, nuts, berries, pods, winged seed, and

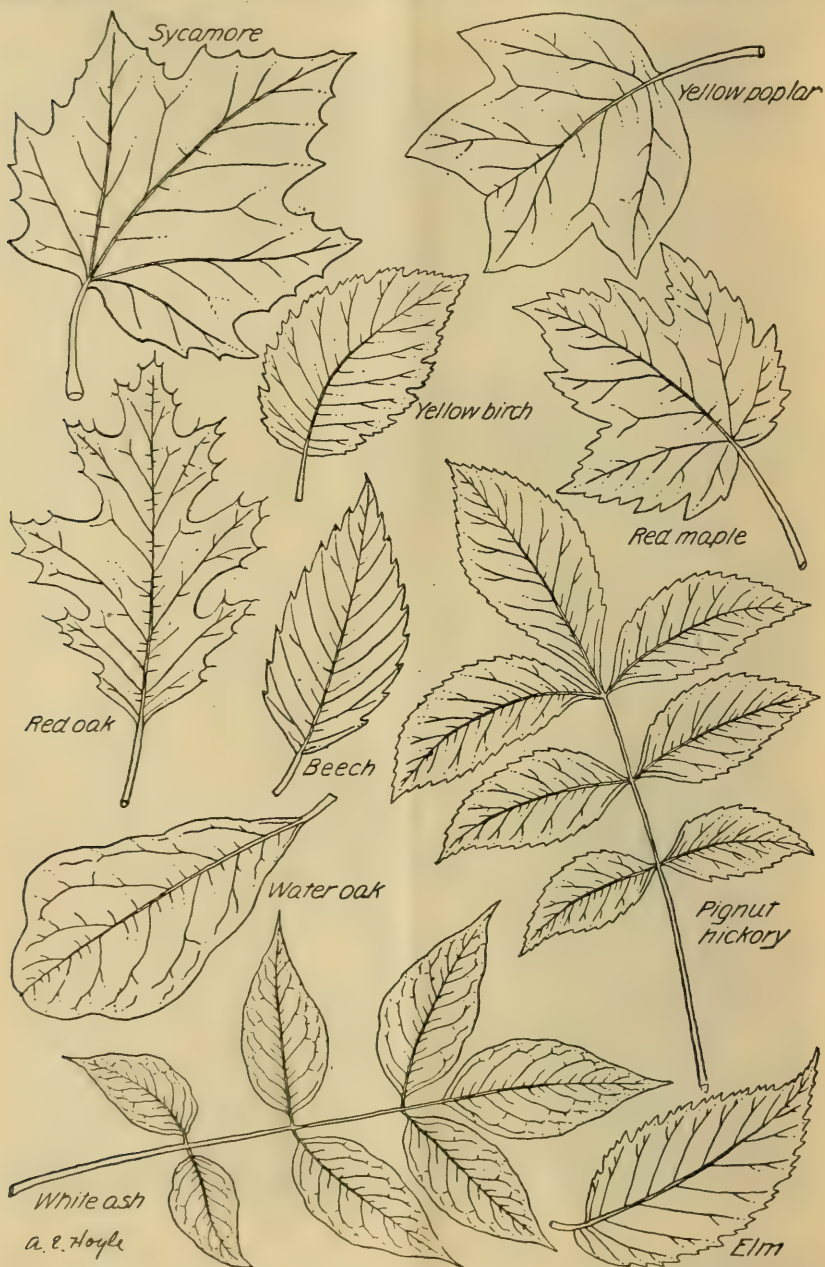


FIG. 3.—Leaf outlines of a few important species of forest trees. (Reduced—not to uniform scale.)

tufted seed of the broadleaf trees and the cones of the conifers, and add to your herbarium.

Buds: As the leaves fall, gather the bare branches and study the winter buds that hold next year's leaves and flowers, from the big bud that tips the horse-chestnut to the long, sharp bud of the beech. Label them as you did the leaves.

Bark: The sycamore bark tells its own story, but do you know the bark of the elm from that of the ash? Contrast the glove-fitting bark of the beech with the rough-and-ready coat of the shagbark hickory.

Branches: Each tree has its own way of branching, though its form is not always so definite as the red cedar spire. What is typical of the white oak bough? The leaves of the scarlet and the pin oak are considerably alike, but what is the character of each tree? Draw a leafless elm.

Flowers: When spring comes and the buds are bursting, do not forget the flowers of the forest trees. They form a clock dial for the advancing year. So as they bloom in succession, bring in the blossoms of the willow, the maple, the elm, and the cottonwood, until you have gathered the last flower of June, and seed are on the wing.

While you have been getting acquainted with your trees, you have learned that they prefer certain localities; you have found the willow by the stream, the yellow or tulip poplar in the valley, the red oak on the higher ground, for one needs much moisture in its soil while another will grow in a drier situation. You have discovered that certain trees "hobnob" together because of similar requirements for soil, moisture, and light. In this way you will learn to group your trees into forest types when you begin your practical work as the forester of your home woodland.

Correlations.—Drawing: Sketch the different types of trees in the district; make drawings or tracings of the different shaped leaves. Mount these drawings and file with other illustrative material.

Language: An account of a field trip carefully written will make a good English exercise. A tree booklet describing the different types of trees, telling where they are found, some of their characteristics and uses, illustrated by original drawings and neatly bound with an attractive cover page, will furnish an excellent drill both in language and in drawing.

Lesson II. LOCATION AND EXTENT OF WOODLANDS.

Problem.—To study places about the farm where trees can be grown profitably.

Sources of information.—Farmers' Bulletins 358, 745, 1071, and 1117; Department Bulletin 481.

Topics for study.—Places about the farm where forest trees and woods should be kept. Timber is a poor land crop. Places where

forest trees are profitable: (1) Poor soils. (2) Steep slopes. (3) Eroding soils. (4) Rocky land. (5) Wet land. (6) Unused corners or waste places.

Extent of woodlands in the locality: Proportion of crop land and woodland. The total acres of woods on 10 to 20 representative farms in the locality.

Practical exercises.—From the data gathered in the survey construct a chart showing the proportion of crop land and woodland, the total crop acreage and the total woodland acreage. Study the places where you find trees growing and list such locations as indicated in topics for study. What type of trees do you find commonly growing in each of these localities? What farms could profitably plant forest trees? What sort of trees should be planted in case a young forest is established?

Correlations.—Drawing: Draw a map of a farm or of the school district, locating the poor soils, steep slopes, eroding soils, rocky land, wet land, unused corners or waste land, and mark on this map the names of the trees that grow on these places or that could be profitably grown thereon.

Language: Write a report showing the advantages of using the poor soils and waste lands for tree planting, giving examples from the farms of the district if possible.

Arithmetic: Problems showing comparative acreage of crop land and woodland, and percentages of each, will be suggested in the study of this lesson.

Lesson III. ECONOMIC VALUE OF THE FOREST.

Problem.—To learn the value of a forest as conservator of soil moisture, as protection against soil erosion, as a shelter against extremes of temperature, and as a means of increasing the farm income.

Sources of information.—Farmers' Bulletins 358, 715, 745, 788, 1071, and 1117; Department Bulletin 481; Yearbook Separate 688; Forestry Misc. F-I.

Illustrative material.—The best illustrative material will be found in a field trip to the woods and field. Actual examples of the use of the trees can be pointed out. If a field trip is not practicable, illustrations may be clipped from papers and magazines showing the erosion on unprotected hillsides and the use of trees as shelters in pastures and about the farm buildings.

Topics for study.—With an acquaintance formed with the different species of trees, it will be worth while to learn their value both as individual trees and associated together in woodlands.

Timber or wood products. Trees, grouped according to their value for wood or timber. (This is expanded in Lesson IV.)

How a forest cover conserves the water from rainfall or melting snow.

Flow of streams from open and forested land; seepage and springs. Protecting watersheds of city reservoirs and headquarters of large streams from erosion and floods. State and municipal forests. The 150,000,000 acres of Government National Forests held for protection of watersheds and streams and for a permanent timber supply. Private owners hold four-fifths of the total standing timber in the United States.

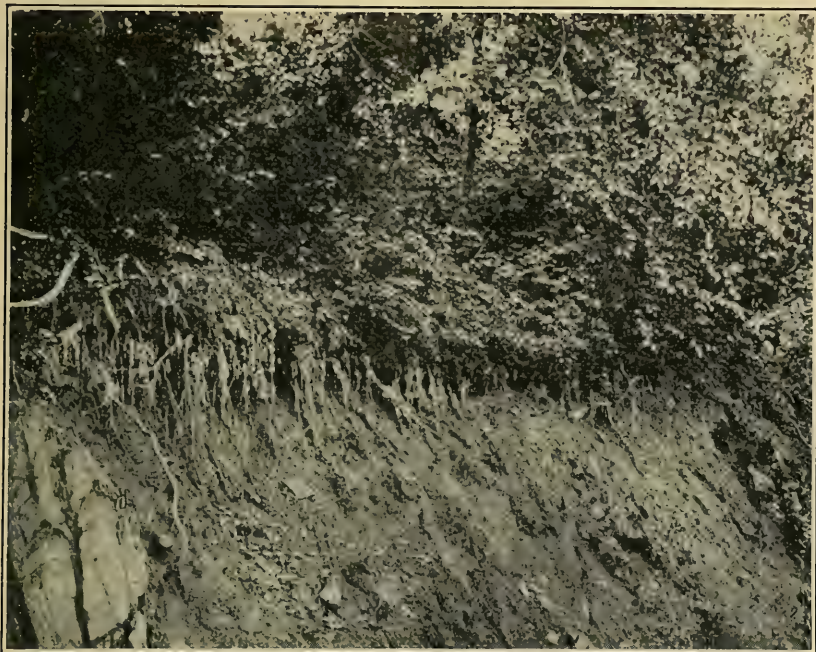


FIG. 4.—The forest floor. Leaves and twig litter on the ground beneath the trees, spongy layer of decomposed vegetable matter or humus, this and the lower layer of soil interlaced with tree roots and rootlets, and the clay subsoil. Dense growth of seedling and sapling trees covering and protecting the soil.

How trees protect the soil against erosion, and the formation of gullies on steep slopes. Examples of local hillsides and regions of the United States.

Effect of woods as shelter against hot dry winds and cold winds for growing grain and fruit crops, live stock, and the farm home. The difference felt in temperature of the air in midsummer out in the open road or field and in the shade of a single tree or of woods. The same as experienced on a cold windy day in winter.

Field study.—In an excursion with the teacher to the hills and fields the class can learn, by actual observation, the bond between the forest and the river.

As soon as the pupil leaves the open and enters the cool shade of the woods he will note the forest floor—the undergrowth of young trees and shrubs, the ferns and moss, and the litter of fallen leaves. With his jackknife, or a trowel, let him dig down beneath this cover into the mold of many years of fallen leaves. The soil will be spongy and moist. What happens when rain falls or snow melts? Under the shadow of the forest it sinks into the spongy earth. (Fig. 4.)

What becomes of the rain and snow that the forest has soaked up like a sponge? Find a spring. This is where the stored water is seeping out to feed the streams. The rainfall that has been held back



FIG. 5.—Effect of deforestation. Washing of soil and devastation of valuable farm lands at the heads of streams.

in the hidden reservoir of the forest is here transformed into a steady supply of water for the pasture, the mill, and the city.

Let the class now return to the open and dig into the soil on the unwooded slope. It will be found dry and hard. What happens when the rain falls or the snow melts on the open hillside? It is not held back and absorbed, but rushes down the slope. In a heavy rain the streams rise rapidly. Perhaps the class will find a bridge that has been carried away in a freshet. Someone may tell of the log bridge on the farm that was destroyed. Then what happens when the winter snow melts upon the unprotected mountain slopes and the spring rains swell the rivers? (Figs 5 and 6.)

While the class is on the open hillside, places will be found where the soil, which has no roots to bind it, has been washed away by the rain, and on some steep slope there will be deep gullies dug into the ground.

Where does the soil go that is washed down the slope? Into the stream. Perhaps the stream carries the silt into the water supply of a city. If there is a river near, a sand bar may be found that has washed down from the hill country. What do muddy rivers mean to the harbors near the coast? Who has seen a dredge at work scooping up the silt to keep the channel free? This means a vast expense to the country.

The pupil who has noted these facts about woodland, soil, and stream, will begin to see the relation which the forests of our country



FIG. 6.—Effect of deforestation. Sand bars in the stream channels. Millions of dollars are spent yearly in dredging our rivers to keep them navigable.

bear to the well-being of the land. The little examples that he finds in his own neighborhood of soil protection and good streams, of erosion and flood damage, are intimations of the larger meaning of the Nation's forests to farm land and industry and commerce. His own home woodland is a part of nature's plan to aid man and his enterprise.

Lesson IV. PRODUCTS FROM THE HOME FOREST.

Problem.—What products from the home forest can be utilized by the farm both for home use and for the market?

Sources of information.—Farmers' Bulletins 516, 715, 1071, and 1117; Department Bulletins 12, 605, and 753; Yearbook Separate 779.

Illustrative material.—Prepare a wall chart showing in a tabulated form the various wood products. In each product column write the name of the tree or, better still, place a sample of the wood that furnished that product. Prepare another chart showing in like manner other timber products such as nuts, roots, bark, gum, and edible fruits, listing the trees the same as in above chart. Any of the products from root, bark, gum, etc., will also make interesting and useful illustrative material.

Topics for study.—Wood, in a rough state, is the principal farm timber product. What kinds of wood are used for the following rough products: (1) Saw logs; (2) poles and piling; (3) fence posts; (4) bolts, blocks, or billets for (a) cooperage, (b) implement handles,



FIG. 7.—High-grade saw logs and rough stave boards cut from woodlands.

(c) wagon and automobile spokes, (d) pulpwood; (5) crossties; and (6) fuel wood. The sizes and other requirements for each of these various wood products, including the species of trees which are best suited and bring highest prices on the market.

Forest trees which produce nuts of commercial value; roots, bark, gum, and edible fruit. List of these products under each head and what they are used for commercially.

Lumber, manufactured from saw logs, is a secondary product from the woodland. (How to measure sawed lumber treated in Lesson VI.) Its manufacture is essentially that of the sawmill man, rather than the farmer.

Practical exercises.—What is the chief use of wood in the district? What other forest products are made or used here? What trees furnish the greater amount of wood? What kind of lumber is

sawed in the district? What becomes of this lumber? If there are any wood product factories in the district, arrange for a trip to the same and study the various processes from the rough wood to the finished products. What timber in the district is most valuable? Why? An interesting study to make is the part forest products play in the construction of machinery, transportation lines, airplanes, etc.

Correlations.—Geography: Trace the timber products of the district to their market. In a like manner locate the source of timber products brought into the district and trace their probable route. On a State map locate the timber areas and learn, if possible, the important kinds of trees in each area. Locate the great lumber regions of the United States. From what ports are forest products of the United States exported?

Arithmetic: Construct problems in which the prices of timber products are used. Use, if possible, the value of the forest products, the price of timber land, and prices of the miscellaneous forest products.

Language: Make a study of the forest products of the district and write a report of your study. Another report of value will be that on the forest products that are imported into the district.

Lesson V. USING FARM TIMBER.

Problem.—To discover the right uses of farm timber.

Sources of information.—Farmers' Bulletins 516, 711, 715, 744, 1023, 1071, and 1117; Department Bulletins 718 and 753; Forestry Bulletins 80 and 144; publications of State foresters and colleges of agriculture.

Illustrative material.—Again a field trip will furnish the best illustrative material for this lesson. Note the height of the stumps where timber has been cut, the careless felling of trees causing the injuring of young trees, the tops and large limbs left in the forest. In the absence of a field trip, pictures may be shown illustrating the points mentioned above.

Topics for study.—The right using of timber on the farm should begin at the time the tree is cut. Waste of good timber in the woods is altogether too common nowadays, with high values on practically every kind of tree.

High stumps mean usually that the best quality of the timber in the tree is wasted. Often the value of the timber left in high stumps is sufficient to pay for all the costs of logging. Saw logs can now be taken profitably from the tops which had to be left only a few years ago. Wherever possible the tops should be worked up into crossties, mine props, or firewood. By careless felling of trees much promising young timber is broken and destroyed.

High grade and valuable timber should not be used in places about the farm where less valuable woods will answer the purpose. Sometimes choice white oak worth \$40 a thousand feet in the log for veneers, is split up into fence posts, or black walnut used for farm gates because it "won't split." Substitutes can be found by children upon inquiry from their parents or neighbors.

Small and young timber cut in making improvement thinnings in overcrowded stands can often be sold or used on the farm for posts, poles, or firewood, instead of being allowed to decay in the woods.

Treating of fence posts: Short-lived woods when soaked in hot and then in cold creosote last from 10 to 20 years as fence posts. As the supply of long-lived woods, such as black locust, osage orange, red



FIG 8.—Small pine logs cut in improving the woods by thinning.

cedar, chestnut, mulberry, and catalpa become scarce, treated fence posts are being increasingly used. Most all farms have some common woods growing, practically all of which take coal-tar creosote readily.

Practical exercises.—In a field trip to the farm forests note what care is taken in felling trees, the disposition of limbs and tops, and the height of the stumps. What examples may be found where an expensive wood is used that could be replaced by a cheaper substitute? What high-priced timber is found in the district? What is the common method of treating fence posts? How do telephone and telegraph companies protect their poles? What good and what bad example of the use of farm timber can you mention?

Correlations.—Language: Make a written or an oral report on the methods of cutting and handling timber on the farm with especial reference to disposing of waste timber. Write a short account on the best methods used in the preservation of timber used in posts, railroad ties, and other lumber.

Arithmetic: Measure the height of stumps in a cut-over piece of timber and calculate the amount of lumber wasted. If one hundred 7-foot black walnut fence posts averaging 5 inches square in size can be replaced by 100 locust or red cedar posts of the same size, calculate, on the basis of local prices, the amount saved by the substitution. If creosoting a softwood post costs 15 cents each for treating but will make it last three times as long as one not treated, assuming average present local prices for labor in replacements and cost of untreated posts, what will be saved in 20 years in fencing a quarter section of land with posts spaced 12 feet apart?

Lesson VI. MEASURING AND ESTIMATING TIMBER.

Problem.—How shall timber be measured and estimated?

Sources of information.—Farmers' Bulletin 715; colleges of agriculture or State foresters' publications; rule for scaling logs, page 39.

Topics for study.—Measuring saw logs: Show how the diameter at the small end is found by measuring inside the bark along an average line, or two measurements taken at right angles and the two averaged. The diameter and length found, the approximate lumber contents is found by referring to a copy of some log rule; probably the most common rule in use is the Doyle, although for small logs under 16 to 20 inches one of the least accurate rules, because from one-third to one-half more lumber is usually sawed out than is shown by the rule. (See Supplement, p. 39.)

How bolts and billets are measured. What makes a standard cord of wood?

Allowances made for defects in saw logs, bolts, or blocks, and in other material.

Estimating standing trees: Finding approximately the contents of standing trees in cords or board feet of lumber by measuring the diameter at breast-height ($4\frac{1}{2}$ feet above the ground), estimating or measuring the number of 16-foot log cuts in the tree, and by using volume tables given on pages 18, 22, and 23 of Farmers' Bulletin 715. Find the merchantable contents of the tree expressed in board feet.

Estimating whole woods: Applying the same method to all the trees on a measured one-tenth or one-quarter acre, and thereby estimating the contents per acre. Recording the measurements by different species on a simple blank form ruled in squares in two directions.

Practical exercises.—This lesson should be essentially one of practice. The class should measure logs according to the Doyle rule, standing trees by the use of volume tables for trees, and cordwood by dimensions of the piles. A good exercise for the more advanced students is to make estimates on logs and standing trees and then by applying the Doyle rule or the volume table test the accuracy of the estimates. The practical value of this lesson is in acquaint-



FIG. 9.—Measuring and estimating the saw timber in a stand of shortleaf pine.

ing the pupils with comparatively easy ways by which they can measure logs and cordwood and estimate the amount of lumber or cordwood in trees.

Correlations.—The operations mentioned in the practical exercises will afford abundant work in calculations and suggest a varied list of arithmetic problems.

LESSON VII. MARKETING FARM TIMBER.

Problem.—How shall the farm timber be marketed to the best advantage.

Sources of information.—Farmers' Bulletins 715 and 1100; bulletins of the State colleges of agriculture and State foresters.

Illustrative material.—Timber price lists. Ad-

dresses of firms dealing in timber. Local prices for cordwood, posts, crossties, and piling.

Topics for study.—Finding the best markets: Before timber is cut its approximate size and amount by species, and its disposal should be determined as definitely as possible. How to find buyers of cut-timber products. How are logs, bolts or billets, piling, posts, crossties, and firewood generally sold? Advertising in the newspapers, consulting neighbors who have recently sold timber, consulting State foresters and reliable experienced men.

The owner protecting himself by a simple form of written contract: Much loss comes to sellers of timber products by failure to

observe this precaution and to have the agreement in proper written form.

Selling timber standing: Selling for a stated sum by the acre, or a lump sum for the whole tract or "boundary."

What to sell and what timber to keep growing in the woods; what timber to sell and what to use at home. Choice logs of certain woods bring high prices, and can be profitably shipped long distances by rail or water.

Cooperative marketing of farm timber: Carload lots of logs, etc., the least amount that can profitably be shipped. Many wood manufacturing concerns buy direct from producers in carload lots. A



FIG. 10.—The best timber brings high prices and can usually be shipped for veneer or quarter-sawed lumber. Several owners can join in marketing a carload lot.

farmer may not have sufficient white oak saw logs or hickory spoke blocks to pay to ship.

Practical exercises.—What timber is being sold in the district? Who is buying it? To what place is it being shipped? What standing timber is sold in the district? What cooperative shipping of timber do you find? Visit a wood yard and note methods of handling the wood and get prices per cord on the different sizes of wood.

Correlations.—Abundant exercises in arithmetic will be suggested by the prices of timber and amounts sold. If a price list of timber and its products at the final market can be had, some interesting problems can be worked out by comparisons with local prices.

For a language exercise make a report on the various kinds of timber marketed, prices paid, methods of transportation, and markets.

Lesson VII. PROTECTING THE WOODS.

Problem.—To learn the best methods of protecting woodlands, and to discover the kind and extent of injury or loss due to forest fires.

Sources of information.—Farmers' Bulletins 173 and 711; Forestry Circular 205; Department Bulletins 308 and 787; Yearbook Separate 548; State publications. The U. S. Department of Agriculture and



FIG. 11.—Oak spoke blocks, piling, and cross-ties ready for shipment.

the agricultural colleges will be glad to render assistance by identifying and furnishing information concerning various forest insects and plants.

Illustrative material.—Pictures of forest fires, burnt over woodlands, forest rangers, their camps and equipment, copies of the United States Forest Regulations, and charts for fire prevention

HELP

PREVENT WOODS FIRES.

BE SURE your match is out before throwing it away.

DON'T throw away burning tobacco.

CHOOSE a safe place and make your camp fire small.

PUT OUT your fire with water and then cover it with earth.

DON'T make large brush heaps. Choose a still day for burning and plow furrows to protect near-by woods.

BE CAREFUL WITH FIRE.

will make excellent illustrative material. Pictures of trees damaged by insects or fungi, samples of damaged wood, samples of insecticides and materials used to prevent insects from damaging trees should also be used.

Topics of study.—Fire, the arch enemy of the forest: It kills large numbers of the smaller trees and kills or weakens the vitality of the older trees; the humus layers over the ground are destroyed. The loss of the protective covering exerts a marked effect in causing the soil to dry out and become hard, as a result of which the rain is shed off rapidly following dry weather, much as when it falls on a house roof. Trees in farm woodlands and city parks are often seen dying at the tops, most usually from this cause.

Forest rangers employed by the States and Government for the administration and protection of the State and National Forests. What type of men are required for forest rangers whose duties require them to live out of doors and ride or work in all kinds of weather? Each National Forest divided into districts in charge of rangers. Fire protective plans worked out in great detail for detecting and fighting fires as soon as possible after they start. Fire-fighting equipment, such as lookout peaks and towers, telephone lines, and fire-fighting tool boxes at convenient points over the forest. Airplane patrol and the wireless telephone are being successfully used.

Protection for State forest lands by similarly organized methods. Federal cooperation with the various States authorized by the Weeks law, for the protecting against fire of headwaters of navigable streams.

The grazing of live stock has much the same effect in removing the protective covering and packing the ground hard. Cattle and horses browse off the tender young seedlings and tramp down the upper soil layers. Sheep and goats are very destructive to young seedlings, particularly when closely herded. Hogs feed upon most kinds of acorns and nuts, although by rooting up the leaf litter they sometimes favorably expose the mineral soil for the quick germination of tree seeds. Hogs are very destructive to the seed or mast of the long-leaf pine, and the young seedlings are killed in large numbers by animals stripping off the thick, sweet, spongy bark from the roots.

Damage by insects: Leaf and inner bark-eating, twig-cutting, bark and woodboring insects. Methods of checking spread of insect infestation by right methods of cutting.

Fungi in forest trees as a source of the dying and injury of many trees. Some trees more immune than others. Importance of keeping woods in a healthy growing condition and rightly cut in order to combat the spread of fungus diseases.



PREVENT FOREST FIRES

Start camp fires only in safe places and extinguish them completely before leaving. Put out any fire discovered or report it to the nearest Forest Officer. The Laws provide heavy penalties for wilful or careless setting of forest fires. A reward will be paid for information leading to conviction of offenders.

Form 986

FIG. 12.—One of the fire signs posted widely in the National Forests.

Practical exercises.—What damages to woodlands occur in the district? What forest protection in use in this locality? Do you find any disease or insect attacking any special group of trees? Are farm animals allowed to graze in the farm woodlands? If so, what damages do you notice?

Lesson IX. IMPROVING THE HOME FOREST BY CUTTING.

Problem.—To study how to improve the home forest by proper cutting.

Sources of information.—Farmers' Bulletins 711, 1071, and 1117; Forestry Bulletins 92 and 96; Department Bulletins 11, 13, 139, and 308; Forestry Misc. R-3; State Foresters' publications.

Illustrative material.—Charts or illustrations showing results of overcrowding and of proper thinning out of forest trees. Pictures showing results of careless felling of trees. If possible, visit a forest where these results can be actually shown by observing rings on stumps or cutting into trees that have been several years previously thinned. In an even-aged group, note different sizes of trees of same age as result of differences in growing space.

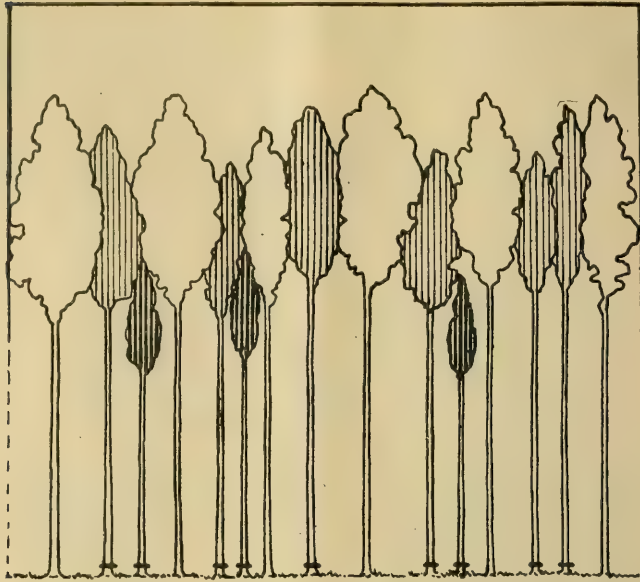
Topics for study.—Cutting the individual tree rightly; why as little as possible of the tree's stump and top should be left in the woods; careful felling of trees. What is liable to happen to trees injured by another falling?

Thinning out overcrowded stands of forest trees. How fewer and fewer trees can grow on an acre as the trees increase in size. Available light supply for growth. Purpose of thinning to utilize timber that would otherwise die and go to waste. Also to stimulate the remaining trees to increased growth, which means increased value.

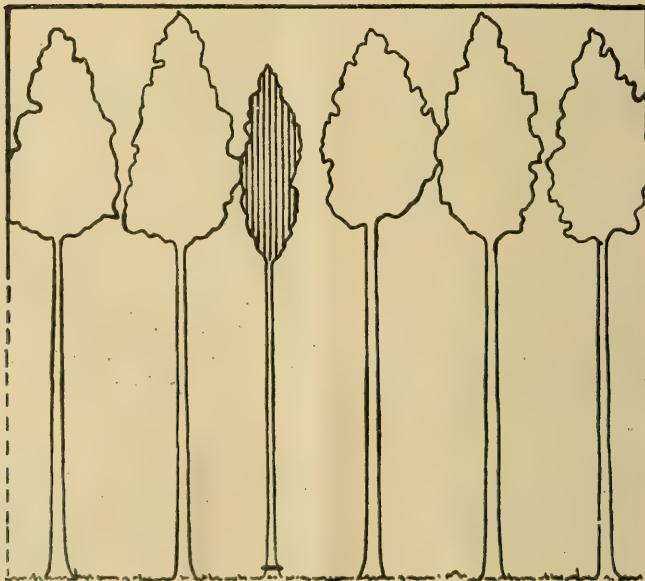
Improve the woods by proper cutting, taking out (1) the mature, (2) broken, crooked, diseased trees, and (3) the slow-growing and less valuable species of trees. Most woodlands have many such trees crowding out young, promising trees of the better kinds. Making woodlands yield a profit on the investment, increasing farm income and the selling value of the farm.

Practical exercises.—The facts taught in this lesson should be verified by actual observation in trips to forests. Study first hand the results mentioned in the lesson. A good project would be the improvement of a forest plat by proper thinning, including the removal of diseased, defective, overcrowded, and dead trees, and undesirable species.

Correlations.—The class in drawing may construct the charts mentioned under "Illustrative material." They should also make drawings of trees showing development under adverse conditions and of others under proper conditions.



A



B

FIG 13.—The growth and value of pine are increased by repeated thinning. The trees removed can generally be used or sold profitably for firewood, treated fence posts, or small timber. A, Before thinning. Fifteen overcrowded trees (shaded trees to be cut). B, The same stand five years after thinning. Six larger and more valuable trees (shaded tree to be cut).

Language: A survey of the general practice of home forest improvement of the district with a written report of the same will afford a very good exercise in language.

Geography: A district or county map locating the farm forest areas and designating those under improvement. An outline map of the State locating the farm forest areas.

Lesson X. GROWTH OF TREES AND FORESTS.

Problem.—To learn how trees and forests grow.

Sources of information.—Farmers' Bulletins 134, 173, and 1071; Forestry Bulletin 92; Department Bulletin 308.

Illustrative material.—Potted seedlings, pots or boxes, and seeds of trees. A chart showing roots, stem, and leaves of a tree. A chart, or better, an actual cross section of a tree stem showing different parts of the stem, such as annual rings, heartwood, sapwood, bark, and cambium. Leaves mounted so that their structure can be studied. Branches showing bud and twig arrangement. Drawings showing shapes of crowns of trees grown in the open and grown in close stands.

Topics for study.—The life of a tree and why it is necessary to know something about how trees live.

The leaves, trunk, and roots, and function of each in the tree's existence. How the tree breathes and gets its food from the soil and air; what travels upward and what downward in the branches and stems. Structure of the leaf and different parts of the trunk.

How the branches lengthen and the tree trunk increases in size; the location, color, and structure of the living tissue or cambium layer. What are annual rings, heartwood, and sapwood?

Requirements for growth: Air, light, moisture, and heat.

Trees in association—a stand. Influence of trees upon each other. Difference, if any, between shape of crowns of open-grown trees and those grown in close stands. Influence of different light and soil moisture supply.

Effect of tree density (number of trees in a given area) upon growth of the individual tree. Natural dying out of trees in close stands with advancing age. Understocked, well-stocked, and overstocked stands and the production of (a) saw timber, and (b) cordwood per acre under each condition.

Practical exercises.—Make the following tests to show requirements for growth. Place a potted forest tree seedling in the dark for a few days; withdraw moisture from one and supply moderate amounts of moisture and excess moisture to other seedlings; subject plants, if possible, to different degrees of heat. Note results. Erect a pole or 1 by 2 inch timber strip close beside a young, thrifty

sapling pine or hardwood. At regular intervals of a week or month, mark on it the total height of the growing tree. Keep a record also of the dates and measured heights.

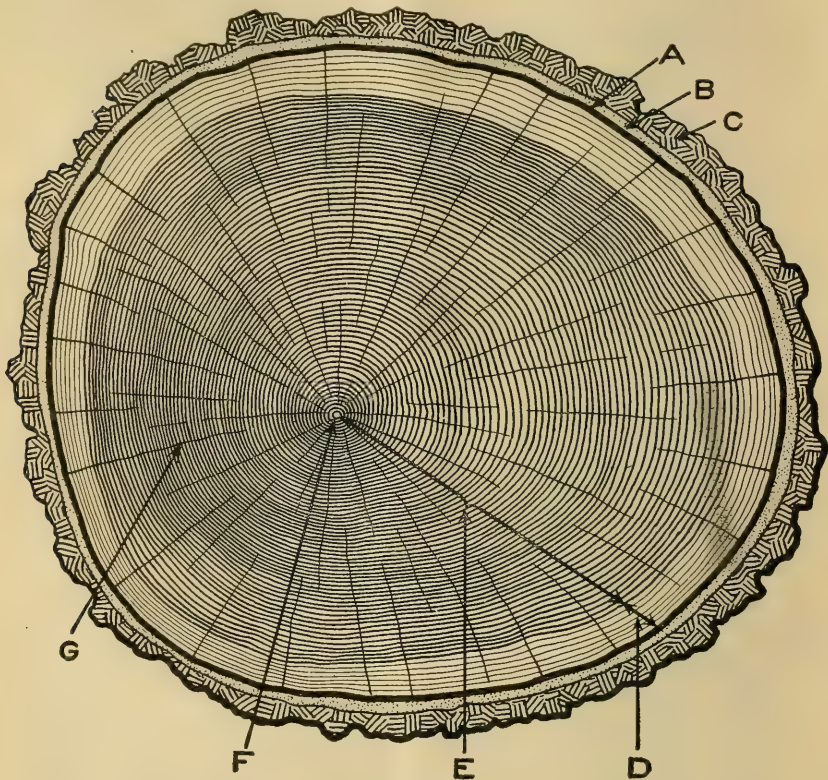


FIG. 14.—How the tree trunk grows. All growth takes place in the cambium, lying between the inner bark and sapwood. This is a very thin layer of living cells which divide and subdivide, forming on the outside bark and on the inside wood (A). The inner bark, or last tissue, is soft and moist. Its function is to carry the food prepared in the leaves to all growing parts of the tree (B). By a gradual change the inner bark passes into outer bark, a corky layer composed of dry, dead leaves. This serves to protect the living stem against evaporation and mechanical injury (C). The woody growth during one season is called an annual ring. In the spring the newly formed cells are thin-walled and spongy, while in midsummer and fall the walls of the cells become thicker and denser. This difference can be distinguished in many kinds of trees as light colored spring wood and darker colored summer wood. Sapwood (D) is the lighter colored band of wood beneath the bark, often from 1 to 2 inches thick. It carries the sap from the roots to the leaves. Heartwood (E) is formed by a gradual change in the sapwood by which it becomes darker, heavier, and often more lasting. Most of the trees, but not all, form heartwood. Pith is the soft tissue on the innermost part of the stem, about which the first woody growth takes place in the newly formed twig (F). From it extend the pith rays (G). These flat bands of the same tissue connect the pith with the various layers of wood and the bark. They transfer and store up food.

Lesson XI. FOREST REPRODUCTION.

Problem.—To learn how trees reproduce themselves.

Sources of information.—Farmers' Bulletins 134, 173, 423, 711, 788, 1071, and 1123; Forestry Bulletins 45, 121, and 244. Forestry

Circulars 45, 81, 99, and 208; Department Bulletin 153; Department Circular 8.

Illustrative material.—Make a collection of seed specimens of the classes indicated under "Topics for study." Either mount these seeds on cardboard or put them in wide-mouth bottles. Clip pictures of young forest growth.

Topics for study.—Seeds: The various devices of nature for dispersing the seed widely. Tree fruits with (a) wings, plumes, etc., (b) pulpy fruit with bony seeds sought by birds, (c) rich nut kernels liked by rodents and birds, and often buried or otherwise



FIG. 15.—Effect of light supply upon the form and commercial value of trees. A, Elm which grew up among other trees of the same height but since cut down. Clear trunks make valuable lumber. B, This elm grew standing in the open. Trees with short limby trunks are useful chiefly as firewood.

stored away, (d) light seeds which float or roll along the bottom of streams. Species of trees whose seeds are (a) carried by wind, (b) water, or by (c) birds and animals. (Fig. 16.)

Sprouts: Different species of trees which reproduce themselves by means of sprouts from stumps. From what part or parts of the stump do sprouts arise? Species which sprout from surface or lateral roots. Influence of the season of the year when cutting is done upon the vigor and growth of sprouts. Influence of age of parent tree upon success of sprouting.

Natural forest reproduction: Young growth. (Fig. 17.) Conditions under which young growth starts in woodlands. A forest

BY WIND

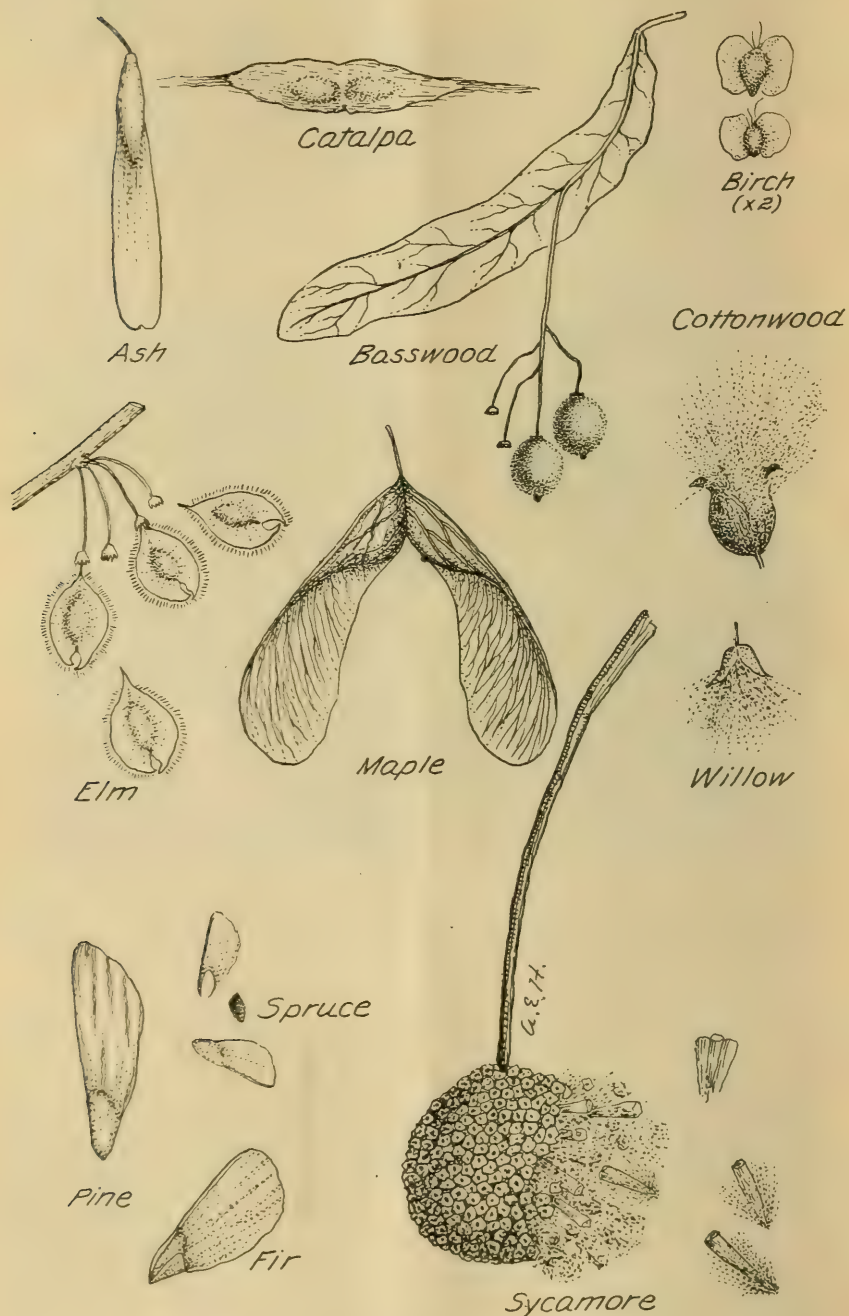


FIG. 16.—How the forest travels: By wind.

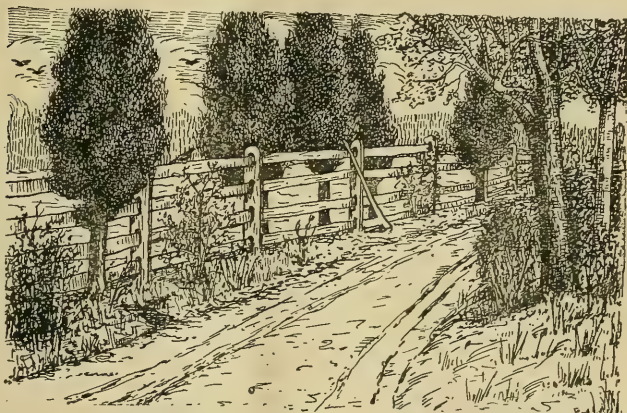
BY ANIMALS

Hickory
Walnut
Butternut
Oak
Honeylocust
Persimmon
Beech



BY BIRDS

Redcedar
Cherry



BY WATER

Cypress
Tupelo gum
Cottonwood
Willows
Maples
etc.



FIG. 16.—How the forest travels: By animals; by birds; by water.

without young growth is like a community without children—it will die out. Need for large numbers of young trees for perpetuation of the forest. Competition and shading out of the weaker seedlings and saplings.

How the forest travels: (a) By wind; (b) by animals, birds, and water. (Fig. 16.)

Age groups of young growth: (a) Seedling, (b) small sapling, (c) large sapling, (d) small pole.



FIG. 17.—Woods with plenty of young growth coming on to take the place of the larger trees when cut.

Starting a young forest by direct seeding or transplanting nursery grown seedlings. Sowing the seed direct where the trees are wanted. Kinds of trees started this way: Usually the species difficult to transplant on account of large, deep taproots, such as hickories, walnuts, some of the oaks, longleaf and some other pines. Collecting the seed. Storing the seed over winter. Sections of the country (north) where seed sowing is best done in the spring and (south) where it may also be done in the fall or early winter. Preparation of the soil and method of planting seed of different kinds. Care of growing seedlings.

Planting seedlings grown in nursery beds. Preparation of nursery beds and sowing of seeds. Kinds of trees commonly raised in nursery beds. Age of seedlings fit for planting. Need for transplanting seedlings in nursery prior to planting out in the woods or fields. Season of year for successful planting and method of planting. Sources of injury or loss, and means of combating. (Fig. 18.)

Regions where forest plantations are needed and commonly started. Purposes for which plantations are set out. Kinds of trees profitable in plantations. Pure and mixed plantations, and advantages of each.



FIG. 18.—Forest plantations are made with small seedlings and no later watering or cultivation are necessary. Fire and grazing stock must be excluded.

Planting steep slopes and eroding soils with forest trees to check soil wastage and land destruction. Kinds of trees suitable for taking hold quickly and multiplying on such dry banks.

Filling up large openings in the woods and improving existing woodlands by planting desirable species of trees.

Utilizing poor soils and so-called waste places about the farm by planting quick-growing, useful kinds of trees: Black locust for fence posts, pine and other species for use as treated fence posts.

Trees about the farm and farmstead for shade, nut production, and ornamental purposes.

Lesson XII. WOODLANDS AND FARM MANAGEMENT.

Problem.—How may the home forest be best managed to make it more valuable, to increase the farm income, and to make the farm more desirable.

Sources of information.—Farmers' Bulletins 635, 711, 715, 745, 1071, and 1117; Department Bulletin 481.

Topics for study.—Review importance and value of woodlands to the farm. The uses of timber on the farm, and importance of having home-grown timber close at hand.

Increasing the farm income by marketing the choice grades of logs and other rough wood products not needed for home use.

Woodlands making farms more desirable and saleable than similar farms without timber. The actual value of the timber and the additional indirect or æsthetic value because of attractiveness, a place for the owner to recreate in, or a cover for small game. People have an inherent fondness for the woods. How the occurrence of woods makes the community a better one in which to live.

Increasing or reducing the area in woods to the point of right proportion of cropland, pastureland, and woodland. The soundness of the farm policy of having permanent woodland on the farm. Proper area in permanent woodland. Kind of soil, topography, and amount of forest land in the locality, and their effect in determining the area of permanent woodland.

Waste or idle land, poor soils, steep slopes, wastes and gullies, rocky and wet lands (fig. 19) made profitable by growing timber.

Handling woodlands so as to keep them at the highest point of production. Overcutting and its ill effect upon the productive power of the forest. Owners to be satisfied with a permanent revenue from the woodland. Difference between a mine and a forest in respect to their producing power.

Woodlands as a source of permanent revenue on the farm. Differences between a timber tract containing thrifty young trees and one with only scattered old trees and much sod and shrubs. The forest capital—the stock of growing trees—must not be too heavily cut. Because of the desire for ready money, there is constant danger of this happening. The apparent returns may be increased for a few years, while the productive capacity of the forest is being reduced below the minimum limit. This point, below which the total amount of growing timber should not be allowed to fall, is about one-half the contents of a fully stocked stand at maturity. If the latter, for example, is 40 cords per acre, then the woods should never contain less than about 20 cords per acre as the growing stock or basis necessary to secure the maximum production. This does not apply to mixed hardwoods cut clean and renewed by sprouting.

Effect of the general rise in the value of all timber products in its relation upon desirability of holding woodlands and keeping them productive. How a forest tract may supply timber yearly for many years and meanwhile increase in value and be worth more at the end of a long period.

Growing timber as a bank account upon which the owners may draw repeatedly without diminishing the capital. A good form of property to be handed down to the children as an inheritance.

Keeping fire out of the woods, cutting the trees carefully, and finding the best markets for excess timber products not needed on the farm are indications of sound judgment in farm management.

Practical exercises.—A survey of the methods of caring for the farm forest should be made. This survey should inquire into the general practice of the district in the care of the forest, the forest products marketed, the utilization of waste or idle lands for forest tracts, the practice of replanting forest plats, and the general relation of the acreage in forest to the crop and pasture acreage. From this survey many facts will be obtained for class discussion in forest management. A field trip into some of the farm woodlands of the district is desirable where the studies made first-hand should include the farm practice on the care of the forest.

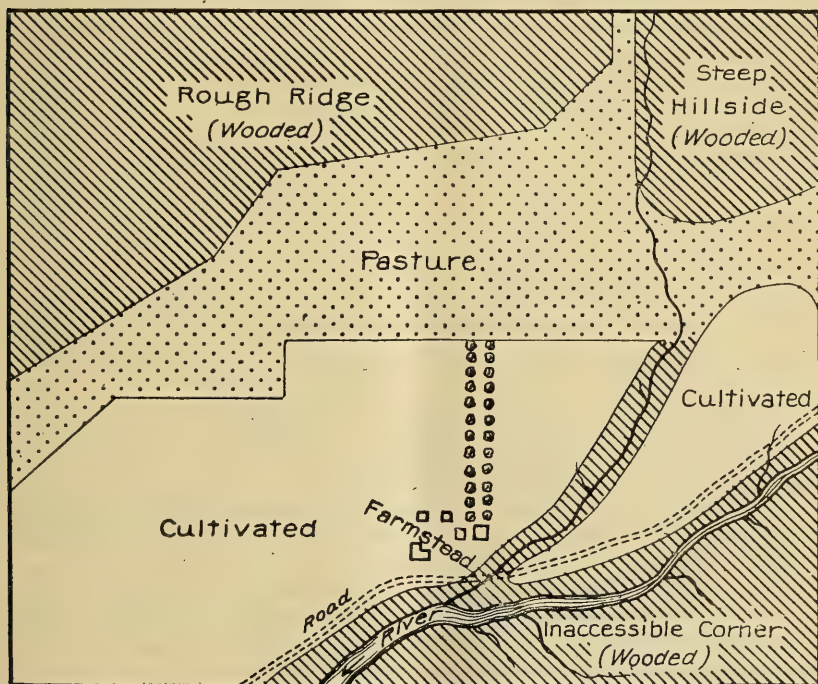


FIG. 19.—Rough, steep, and poor lands and inaccessible parts of the farm increasing farm income by growing trees in permanent woodlands.

SUPPLEMENT.

PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO FORESTRY ON FARM WOODLANDS.

DIRECTIONS FOR REQUESTING THESE PUBLICATIONS.

(a) For publications available for free distribution, application should be made to the Chief of Publications, U. S. Department of Agriculture, Washington, D. C. (b) For publications for sale, application should be made to the Superintendent of Documents, Government Printing Office, Washington, D. C., inclosing the money in the form of cash or money order (stamps not accepted).

The following lists are subject to frequent changes as available supplies become exhausted and new publications are added.

FARMERS' BULLETINS AVAILABLE FOR FREE DISTRIBUTION.

- 173. Primer of Forestry, Part I.
- 358. Primer of Forestry, Part II.
- 468. Forestry in Nature Study.
- 516. Production of Maple Sugar and Sirup.
- 622. Basket Willow Culture.
- 635. What the Farm Contributes Directly to the Farmer's Living.
- 711. Care and Improvement of Farm Woods.
- 715. Measuring and Marketing Farm Timber.
- 742. The White Pine Blister Rust.
- 744. Preservative Treatment of Farm Timbers.
- 745. Waste Land and Wasted Land on Farms.
- 788. The Windbreak as a Farm Asset.
- 888. Advice to Forest Planters in the Plains Region.
- 1023. Machinery for Cutting Firewood.
- 1071. Making Woodlands Profitable in the Southern States.
- 1100. Cooperative Marketing of Woodland Products.
- 1117. Forestry and Farm Income.
- 1123. Growing and Planting Hardwood Seedlings on the Farm.

OTHER DEPARTMENT PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

- Forestry Bulletin 111, Lightning in Relation to Forest Fires.
- Forestry Bulletin 114, Forestry Conditions in Louisiana.
- Department Bulletin 55, The Balsam Fir.
- Department Bulletin 152, The Eastern Hemlock.
- Department Bulletin 153, Forest Planting in the Eastern United States.
- Department Bulletin 481, Status and Value of Farm Woodlots in the Eastern United States.
- Department Bulletin 544, The Red Spruce: Its Growth and Management.
- Department Bulletin 605, Lumber Used in the Manufacture of Wooden Products.
- Department Bulletin 683, Utilization of Elm.
- Department Bulletin 718, Small Sawmills.
- Department Bulletin 753, Use of Wood for Fuel.

Department Bulletin 787, Protection from the Locust Borer.

Department Circular 8, Arbor Day.

Department Circular 64, How Lumber is Graded.

Yearbook Separate 548, Fire Prevention and Control on the National Forests.

Yearbook Separate 688, Farms, Forests, and Erosion.

Yearbook Separate 779, Farm Woodlands and the War.

Department Misc. F-I, Government Forest Work (booklet).

Forestry Circular 205, Forest Fire Protection Under Weeks Law in Cooperation with the States.

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS.

Farmers' Bulletin 134, Tree Planting for Rural School Grounds. Price, 5 cents.

Farmers' Bulletin 423, Forest Nurseries for Schools. Price, 5 cents.

Farmers' Bulletin 582, Uses for Chestnut Timber Killer by the Bark Disease. Price, 5 cents.

Forestry Bulletin 17, Check List of the Forest Trees of the United States. Price, 15 cents.

Forestry Bulletin 36, The Woodman's Handbook. Price, 25 cents.

Forestry Bulletin 40, New Method of Turpentine Orcharding. Price, 20 cents.

Forestry Bulletin 45, Planting of White Pine in New England. Price, 20 cents.

Forestry Bulletin 58, The Red Gum. Price, 15 cents.

Forestry Bulletin 61, Terms Used in Forestry and Logging. Price, 5 cents.

Forestry Bulletin 66, Forestry Belts of Western Kansas and Nebraska. Price, 10 cents.

Forestry Bulletin 80, The Commercial Hickories. Price, 15 cents.

Forestry Bulletin 90, Relation of Light Chipping to the Commercial Yield of Naval Stores. Price, 10 cents.

Forestry Bulletin 92, Light in Relation to Tree Growth. Price, 10 cents.

Forestry Bulletin 96, Second Growth Hardwoods in Connecticut. Price, 15 cents.

Forestry Bulletin 99, Uses of Commercial Woods of United States: Pines. Price, 15 cents.

Forestry Bulletin 102 Identification of the Important North American Oak Woods. Price, 10 cents.

Forestry Bulletin 104, Principles of Drying Lumber. Price, 5 cents.

Forestry Bulletin 117, Forest Fires. Price, 10 cents.

Forestry Bulletin 121, Forestation of the Sand Hills of Nebraska and Kansas. Price, 10 cents.

Forestry Circular 45, Forest Planting in Eastern Nebraska. Price, 5 cents.

Forestry Circular 62, Shagbark Hickory (Planting Leaflet). Price, 5 cents.

Forestry Circular 63, Basswood (Planting Leaflet). Price, 5 cents.

Forestry Circular 65, Norway Spruce (Planting Leaflet). Price, 5 cents.

Forestry Circular 66, White Elm (Planting Leaflet). Price, 5 cents.

Forestry Circular 75, Hackberry (Planting Leaflet). Price, 5 cents.

Forestry Circular 77, Cottonwood (Planting Leaflet). Price, 5 cents.

Forestry Circular 81, Forest Planting in Illinois. Price, 5 cents.

Forestry Circular 88, Black Walnut (Planting Leaflet). Price, 5 cents.

Forestry Circular 89, Tamarack (Planting Leaflet). Price, 5 cents.

Forestry Circular 90, Osage Orange (Planting Leaflet). Price, 5 cents.

Forestry Circular 92, Green Ash (Planting Leaflet). Price, 5 cents.

Forestry Circular 99, Suggestions for Forest Planting on the Semiarid Plains. Price, 5 cents.

- Forestry Circular 118, Management of Second Growth in the Southern Appalachians. Price, 5 cents.
- Forestry Circular 208, Extracting and Cleaning Forest Tree Seed. Price, 5 cents.
- Department Bulletin 11, Forest Management of Loblolly Pine in Delaware, Maryland, and Virginia. Price, 15 cents.
- Department Bulletin 12, Uses of Commercial Woods of the United States: Beech, Birches, Maples. Price, 10 cents.
- Department Bulletin 13, White Pine Under Forest Management. Price, 15 cents.
- Department Bulletin 139, Norway Pine in the Lake States. Price, 10 cents.
- Department Bulletin 212, Observations on the Pathology of the Jack Pine. Price, 5 cents.
- Department Bulletin 247, A Disease of Pines Caused by *Cronartium Pyriforme*. Price, 5 cents.
- Department Bulletin 272, The Southern Cypress. Price, 20 cents.
- Department Bulletin 285, The Northern Hardwood Forest. Price, 20 cents.
- Department Bulletin 299, The Ashes: Their Characteristics and Management. Price, 25 cents.
- Department Bulletin 308, Shortleaf Pine: Its Economic Importance and Forest Management. Price, 15 cents.
- Department Bulletin 316, Willows: Their Growth, Use and Importance. Price, 15 cents.
- Department Bulletin 638, Forestry and Community Development. Price, 10 cents.

STATE FORESTRY DEPARTMENTS.

Thirty-three States have Departments of Forestry, all of which publish more or less material on varied phases of the subject. Applications should be addressed to the State Foresters at the following places:

- Alabama, State Commission of Forestry, Montgomery.
- California, State Board of Forestry, Sacramento.
- Colorado, State Board of Forestry, Fort Collins.
- Connecticut, State Forester (under Agricultural Experiment Station), New Haven.
- Idaho, Fire Warden System (under State Board of Land Commissioners), Boise.
- Illinois, State Forester, Urbana.
- Indiana, State Board of Forestry, Indianapolis.
- Iowa, State Forestry Commissioner, Des Moines.
- Kansas, State Agricultural College, Manhattan.
- Kentucky, Commissioner of Agriculture, Frankfort.
- Louisiana, Department of Conservation, New Orleans.
- Maine, Forest Commissioner, Augusta.
- Maryland, State Board of Forestry, Baltimore.
- Massachusetts, State Forester, Boston.
- Michigan, Public Domain Commission, Roscommon.
- Minnesota, State Forestry Board, St. Paul.
- Montana, State Board of Land Commissioners, Helena.
- New Jersey, Department of Conservation and Development, Trenton.
- New York, Division of Lands and Forests, Albany.
- North Carolina, Geological and Economic Survey, Chapel Hill.
- Ohio, Department of Forestry, Wooster.

Oregon, State Board of Forestry, Salem.
 Pennsylvania, Department of Forestry, Harrisburg.
 Rhode Island, Commissioner of Forestry, Chepachet.
 South Dakota, Forest Supervisor, Custer.
 Tennessee, State Geological Survey, Nashville.
 Texas, Agricultural and Mechanical College, College Station.
 Vermont, Department of Agriculture, Montpelier.
 Virginia, State Forester, University.
 Washington, State Board of Forest Commissioners, Olympia.
 West Virginia, Forest, Game, and Fish Department, Philippi.
 Wisconsin, State Conservation Commission, Madison.

DOYLE RULE FOR SCALING LOGS.¹

Diameter of log (small end, inside bark).	LENGTH OF LOG IN FEET.																			
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20					
	BOARD FEET.																			
Inches.																				
6.....	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5					
7.....	3	4	4	5	5	6	7	8	8	9	9	10	10	11	11					
8.....	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20					
9.....	9	11	12	14	16	17	19	20	22	23	25	27	28	30	31					
10.....	13	16	18	20	22	25	27	29	31	34	36	38	40	43	45					
11.....	18	21	24	28	31	34	37	40	43	46	49	52	55	58	61					
12.....	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80					
13.....	30	35	40	46	51	56	61	66	71	76	81	86	91	96	101					
14.....	37	44	50	56	62	69	75	81	87	94	100	106	112	119	125					
15.....	45	53	60	68	76	83	91	98	106	113	121	129	136	144	151					
16.....	54	63	72	81	90	99	108	117	135	144	144	162	162	171	180					
17.....	63	74	84	95	106	116	127	137	148	158	169	180	190	201	211					
18.....	73	86	98	110	122	135	147	159	171	184	196	208	220	233	245					
19.....	84	98	112	127	141	155	169	183	197	211	225	239	253	267	281					
20.....	96	112	128	144	160	176	192	208	224	240	256	272	288	304	320					
21.....	108	126	144	163	181	199	217	235	253	271	289	307	325	343	361					
22.....	121	142	162	182	202	223	243	263	283	304	324	344	364	385	405					
23.....	135	158	180	203	226	248	271	293	316	338	361	384	406	429	451					
24.....	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500					
25.....	165	193	220	248	276	303	331	358	386	413	441	469	496	524	551					
26.....	181	212	242	272	302	333	363	393	423	454	484	514	544	575	605					
27.....	198	231	264	298	331	364	397	430	463	496	529	562	595	628	661					
28.....	216	252	288	324	360	396	432	468	504	540	576	612	648	684	720					
29.....	234	273	312	352	391	430	469	508	547	586	625	664	702	742	781					
30.....	253	296	338	380	422	465	507	549	591	634	676	718	760	803	845					
31.....	273	319	364	410	456	501	547	592	638	683	729	775	820	866	911					
32.....	294	343	392	441	490	539	588	637	686	735	784	833	882	931	980					
33.....	315	368	420	473	526	578	631	683	736	788	841	894	946	999	1,051					
34.....	337	394	450	506	562	619	675	731	787	844	900	956	1,012	1,069	1,125					
35.....	360	420	480	541	601	661	721	781	841	901	961	1,021	1,081	1,141	1,201					
36.....	384	448	512	576	640	704	768	832	896	960	1,024	1,088	1,152	1,216	1,280					
37.....	408	476	544	613	681	749	817	885	953	1,021	1,089	1,157	1,225	1,293	1,361					
38.....	433	506	578	650	722	795	867	939	1,011	1,084	1,156	1,228	1,300	1,373	1,445					
39.....	459	536	612	689	766	842	919	995	1,072	1,148	1,225	1,302	1,378	1,455	1,531					
40.....	486	567	648	729	810	891	972	1,053	1,134	1,215	1,296	1,377	1,458	1,539	1,620					

To find the number of board feet in a log without using the above table according to the Doyle rule: Deduct 4 inches from the diameter of the smaller end, square one-fourth the remainder, and multiply the product by the length in feet.

¹ For information regarding the advisability of using different log scales see U. S. Dept. Agr., Farmers' Bul. 715.

KEY TO COMMON KINDS OF TREES.¹

The following key is intended only as a guide in the identification of the more common kinds of trees. It is based on prominent, distinctive characteristics which can readily be observed by those who have no special training in botany. Most of the terms used require no explanation.

To use the key, decide first, by an examination of the leaf, in which of the following seven sections your tree belongs; then turn to that section, and from the descriptions there given determine what kind of tree it is.

	Section.
Trees with needles or scale-like leaves, mostly evergreens, bearing cones—	I
Trees with broad leaves:	
Leaves simple—	
Alternately attached to twigs—	
With toothed edges—	II
Edges neither toothed nor notched—	III
Opposite on twigs—	
With toothed edges—	IV
Edges neither toothed nor notched—	V
Leaves compound—	
Alternately attached to twigs—	VI
Opposite on twigs—	VII

THE CONIFEROUS² TREES.

I. TREES WITH NEEDLES OR SCALE-LIKE LEAVES, MOSTLY EVERGREEN, BEARING CONES.

A. Leaves needle-shaped:

(1) Leaves clustered—

- (a) Leaves long, from 1 to 18 inches, 2 to 5 in a cluster. Cones large, with many thick, woody scales— (Pinus) Pine.
- (b) Leaves short (less than 2 inches long) in brush-like clusters of 12 to 40; falling off in winter. Cones very small, with thin scales; remaining on tree for one or more seasons — (Larix) Larch.³

(2) Leaves single—

- (a) Leaves scattered around twigs; falling off when dry or dead. Cones elongated, with thin scales. Twigs roughened by leaf-scars.
- (x) Leaves stiff, often sharp-pointed and more or less four-sided— (Picea) Spruce.
- (y) Leaves soft, flat, rounded, or notched at ends, the bases abruptly contracted into thread-like stems — (Tsuga) Hemlock.
- (b) Leaves in two distinct rows, one on each side of the twig; falling off in late autumn or winter. Cones small, ball-like— (Taxodium) Bald cypress.

¹ This key and the following tree descriptions are by William H. Lamb, Scientific Assistant in Dendrology, Forest Service.

² Cone-bearing.

³ The larches are peculiar in having single, scattered leaves on the new or terminal twigs produced each season. These should not be mistaken for the "single" leaves borne throughout by other kinds of evergreens.

A. Leaves needle-shaped—Continued.

(2) Leaves single—Continued.

- (c) Leaves often in two rows on the tops and sides of the twigs; leaves on lower branches mostly flat, those on upper branches stouter. Cones long, erect, forming only on upper side of topmost branches; the scales falling off in autumn, leaving spike-like central axes of the cones attached----- (Abies) Fir.

B. Leaves scale-like, pointed, overlapping closely on flat or four-sided twigs.

- (1) Twigs four-sided. Cones round or ball-like, with small, thick scales; seed with very narrow, hard wings-- (Cupressus) Cypress.
- (2) Twigs flattened.

- (a) Cones elongated, with only a few thin scales; bent back on branches----- (Thuja) Arborvitæ.

- (b) Cones round, very small, berry-like with thin scales; seeds with a broad, thin wing on two sides.

(Chamæcyparis) Cedar.

- (c) Cones berry-like (showing no separation into scaly parts), Leaves either short, scale-like, and sharp-jointed, or much longer, needle-like, standing out loosely, and attached in pairs or in threes on the twigs.

(Juniperus) Juniper.

THE BROADLEAF TREES.

II. LEAVES SIMPLE, ALTERNATE, WITH TOOTHED EDGES.

A. Leaves deeply lobed, or with large notches.

- (1) Leaves as wide as they are long. Fruit, a swinging ball, 1 to 1½ inches in diameter.

- (a) Leaves with finely toothed margins; star-shaped, the divisions pointed. Fruit, bur-like balls, from which, when ripe, small, winged seeds may be shaken. Bark rough.

(Liquidambar) Sweet gum.

- (b) Leaves with smooth margins, 3 to 5 inches long, pointed lobes, the space between the lobes rounded. Fruit, a rough ball, easily broken when ripe; composed of closely packed, long, narrow seeds which have hair-like bristles at their lower ends and are attached to a bullet-like central part. Old bark of trunks and large limbs peeling off in thin, curled pieces, leaving pale inner bark showing in irregular patches----- (Platanus) Sycamore.

(2) Leaves longer than wide.

- (a) Leaves large, with deep, round-topped, or pointed lobes. Fruit, an acorn, resting in a separable cup.

(Quercus) Oak.

- (b) Leaves small, with little, sharp teeth on margin. Twigs bearing sharp thorns. Fruit small (like a little apple), round, with bony seeds (hard core).

(Cratægus) Hawthorn.

B. Leaves one-sided (one side of leaf shorter at base than the other side).

- (1) Leaves large, oval, 5 to 10 inches long, heart-shaped. Fruit, a cluster of small, woody balls $\frac{1}{8}$ to $\frac{1}{2}$ inch in diameter, hanging from a narrow, leaf-like blade----- (Tilia) Basswood.

B. Leaves one-sided—Continued.

- (2) Leaves 3-veined at base, with long, tapering points, which generally turn to one side; edges smooth, or with small teeth of uniform size. Fruit, a small berry about $\frac{1}{4}$ inch in diameter.

(Celtis) Hackberry.

- (3) Leaves with straight veins, oval; edges double-toothed (little teeth on the larger ones). Fruit in clusters, dry, flat, with papery wings all around the seeds.----- (Ulmus) Elm.

C. Leaves even sided (both sides of leaf the same length).

- (1) Leaves oval, evergreen thick, with short needle-like teeth. Fruit, a bright red berry.----- (Ilex) Holly.

- (2) Leaves more or less elongated, with one tooth at the end of each side vein.

(a) Trees with smooth, bluish-gray bark, and long, pointed, chestnut-brown buds. Fruit, a small, three-cornered nut, in a spiny husk which splits open at the top into three parts.----- (Fagus) Beech.

(b) Trees with ridged, grayish-brown bark. Fruit, a large, round nut in a thick husk covered with dense, needle-like spines; the husk splits open from the top into 3 or 4 divisions.----- (Castanea) Chestnut.

- (3) Leaves very narrow, finely toothed. Small branches slender, usually tough. Fruit, a long cluster of little pods filled with "cotton"----- (Salix) Willow.

- (4) Leaves somewhat triangular in outline, broad at base, large-toothed. Buds of some species coated with aromatic gum. Branches coarse. Fruit, a long cluster of little pods filled with "cotton." (Populus) Poplar.

- (5) Leaves oval, pointed, with saw-like teeth.

(a) Fruit like a tiny pine cone.

(x) Bark of trunk and branches peeling off in thin sheets. Leaves double-toothed (little teeth on the larger ones.) Fruit ("cones") scaly, falling apart when ripe; seeds with gauze-like wings on two sides.----- (Betula) Birch.

(y) Bark smooth or broken, but not peeling. Leaves with small teeth. "Cones" hard, woody, not falling apart; seed with narrow wings on two sides.----- (Alnus) Alder.

(b) Fruit, a berry; fleshy, edible.

(x) Leaves large, 3-veined at base, often irregularly, deeply lobed; containing milky juice. Fruit similar in appearance to a blackberry.

(Morus) Mulberry.

(y) Leaves small or medium-sized, feather-veined; containing green juice; fruit (cherry or plum) with one seed.

(i) Seed ("stone") flattened. Fruit large and short-stemmed.---- (Prunus) Plum.

(ii) Seed round. Fruit small and long-stemmed ----- (Prunus) Cherry.

III. LEAVES SIMPLE, ALTERNATE, EDGE NEITHER TOOTHED NOR NOTCHED.

A. Leaves with deep lobes.

- (1) Leaves with blunt ends (appearing as if cut off), and with two, pointed, side lobes. Flowers tulip-like. Fruit cone-like, pointed, upright, composed of long, thin, overlapping, winged seeds. Bruised twigs have a peppery odor. (Liriodendron) Tulip Poplar.
- (2) Leaves with rounded ends; oval, often with a lobe on one side, making the leaf mitten-shaped. Bruised twigs and inner bark of trunk sweet-smelling. (Sassafras) Sassafras.

B. Leaves without lobes.

(1) Bruised twigs with peppery odor.

- (a) Leaves oval (evergreen in one species) or elongated, pointed, large. Flowers large, at ends of branches. Fruit cone-like, with a bright red seed in each division. (Magnolia) Magnolia.

(2) Bruised twigs without peppery odor.

- (a) Leaves broader at top than at the base, 8 to 12 inches long, with very short leafstalk. Fruit fleshy, elongated, 3 to 4 inches long, with thick, brown skin when ripe, and large, bony, flat seeds. Buds brown and hairy.

(Asimina) Papaw.

(b) Leaves broadest at middle, oval, 3 to 10 inches long.

- (x) Fruit short-stalked, round, 1 to 1½ inches in diameter; when ripe pale orange color, surrounded at base with old flower-cup; very bitter, but edible after frost.

(Diospyros) Persimmon.

- (y) Fruit long-stalked, elongated or round, solitary or in pairs, with thin flesh and a rigid stone or seed.

(Nyssa) Gum.

- (c) Leaves rounded or heart-shaped, 3 to 5 inches across. Flowers pea-like, pink, appearing before the leaves. Fruit, a dry flat pod, 2½ to 3½ inches long; in dense clusters on sides of branches; seeds, hard, small, oblong, ¼ inch long.

(Cercis) Red bud.

(3) Bruised or cut twigs and leaves with milky juice.

- (a) Leaves with narrow points. Twigs bearing thorns. Fruit, a large, orange-like, rough ball, 4 to 6 inches in diameter.

(Toxylon) Osage orange.

IV. LEAVES SIMPLE, OPPOSITE, WITH TOOTHED EDGES.

- A. Leaves with large (often lobe-like) teeth. Fruit in pairs, each part with a conspicuous, flat, very thin wing. Fruit matures in spring or in autumn, when it becomes dry and yellowish-brown.

(Acer) Maple.

V. LEAVES SIMPLE, OPPOSITE, EDGES NEITHER TOOTHED NOR NOTCHED.

- A. Leaves very large, heart-shaped. Flowers showy, trumpet-like, in large clusters. Fruit, a long, cylindrical pod, 6 to 14 inches long, containing closely packed, flat, dry seeds, with fringed wings at each end.

(Catalpa) Catalpa.

- B. Leaves rather small, oval, tapering at base and point. Flowers conspicuous, white (occasionally rosy), appearing with the expanding leaves. Fruit, a small cluster of two-seeded berries, turning red in autumn.

(Cornus) Dogwood.

VI. LEAVES COMPOUND, ALTERNATELY ATTACHED TO TWIGS.

A. Leaflets small, many, attached along two sides of a main stem. Fruit, a flat, bean-like, dry or fleshy pod.

- (1) Leaflets with small, wavy teeth. Pods flat, broad, long, often twisted, thin-skinned, with thick, cheesy, sweetish pulp about seeds. Trees with long, keen, branched thorns.

(Gleditsia) Honey locust.

- (2) Leaflets not toothed.

(a) Twigs with pairs of short, keen thorns. Leaflets rounded at ends. Flowers showy white, in large clusters. Pods small, flat, thin, dry, with small seeds--- (Robinia) Black locust.

(b) Twigs thornless. Leaflets oval, pointed. Flowers greenish, with violet odor. Pods large, flat, thick, with jelly-like pulp (poisonous) around the large, black-brown seeds.

(Gymnocladus) Coffee tree.

B. Leaflets large. Fruit, a hard-shelled nut, with a separable husk.

- (1) Leaflets narrow at base becoming larger at outer end. But light-colored, in a husk which separates more or less completely into four parts when ripe----- (Hicoria) Hickory.

- (2) Leaflets broad at base, becoming narrower at outer end. Nut dark, rough, in a fleshy husk which is inseparable by any natural divisions and turns black when old. Pith of twigs forms numerous cross-partitions ----- (Juglans) Walnut.

VII. LEAVES COMPOUND, OPPOSITE ON TWIGS.

A. Leaflets arranged along two sides of a main leafstalk, with a leaflet at the end.

- (1) Leaflets generally 3 (sometimes 5), toothed only near the ends. Fruit, a cluster of dry, winged seeds, arranged in pairs like those of maple----- (Acer) Boxelder.⁴

- (2) Leaflets generally more than 3 (3 to 11), and either not toothed or with small teeth. Fruit, a cluster of a single-winged, dry, oar-shaped "seeds" ----- (Fraxinus) Ash.

B. Leaflets (5 to 9) clustered at end of a main leaf-stem. Fruit, a shiny, brown nut in a thick, warty or prickly husk, which separates into several parts----- (Æsculus) Buckeye.

ONE HUNDRED IMPORTANT FOREST TREES.⁵

Name.	Distribution.	Remarks.
1. White pine (<i>Pinus strobus</i>)..	Northeastern and Lake States and Appalachian Mountains	Fine timber tree; leaves in clusters of 5, 3 to 5 inches long.
2. Jack pine (<i>Pinus divaricata</i>) ⁶ (<i>Pinus banksiana</i>).	Northern tree, best growth north of Lake Superior.	Common on sandy soil; leaves in clusters of 2, $\frac{3}{4}$ to 1 $\frac{1}{2}$ inches long.
3. Red or Norway pine (<i>Pinus resinosa</i>).	Northern tree, associated with white pine.	Leaves in clusters of 2, 5 to 6 inches long.
4. Pitch pine (<i>Pinus rigida</i>)....	Northeastern and middle Atlantic States.	Leaves in clusters of 3, 3 to 5 inches long.
5. Loblolly pine (<i>Pinus taeda</i>)..	Southeastern States Coastal plain, Delaware to Texas.	Leaves in clusters of 3, 6 to 9 inches long. Cone, 2 to 3 inches in diameter.
6. Shortleaf pine (<i>Pinus echinata</i>).	Middle Atlantic and Southern States, with hardwood trees. Piedmont uplands, New Jersey to Texas.	Leaves in clusters of 2 and sometimes 3, 3 to 5 inches long. Cone small, 1 to 2 inches in diameter.

⁴ Boxelder, a true maple, differs from the others in having compound leaves.

⁵ Eastern half of United States. Most of these are important as commercial timber trees; a few, however, are small sized and included because of their botanical importance and wide occurrence in mixture with timber trees, particularly in second-growth forests.

⁶ Some species are known by more than one scientific name because of lack of agreement among botanists. The first name given is to be preferred.

ONE HUNDRED IMPORTANT FOREST TREES—Continued.

Name.	Distribution.	Remarks.
7. Spruce pine (<i>Pinus glabra</i>)..	Southeastern States along coast	Leaves in clusters of 2, 1½ to 3 inches long.
8. Scrub pine, Jersey pine (<i>Pinus virginiana</i>).	Middle Atlantic States.....	Leaves in clusters of 2, 1½ to 3 inches long.
9. Pond pine (<i>Pinus serotina</i>)..	Southeastern States in Coastal Plain. Scattering.	Leaves 6 to 8 inches long, tree similar to pitch pine, but cones remain closed for several years. Cone rounded.
10. Slash pine (Cuban pine) (<i>Pinus caribæa</i>).	Southeastern States in poorly drained soils; uplands in Georgia, associated with longleaf pine.	Leaves in clusters of 2, sometimes 3, 8 to 12 inches long. Important turpentine tree.
11. Longleaf pine (<i>Pinus palustris</i>).	South Atlantic and Gulf States.	Leaves in clusters of 3, 8 to 18 inches long. Important turpentine tree.
12. Tamarack or Larch (<i>Larix laricina</i> , <i>Larix americana</i>).	Northeastern States, best growth in Canada.	Leaves needle-shape, ½ to 1½ inches long, in dense brush-like clusters, falling off in winter.
13. White spruce (<i>Picea canadensis</i>).	Northeastern States and in northern Rocky Mountains.	Leaves ½ to ¾ inch long, arranged singly around the smooth twigs.
14. Black spruce (<i>Picea mariana</i>).	Northeastern States.....	Similar to white spruce, but twigs are minutely hairy.
15. Red spruce (<i>Picea rubra</i>)....	Northeastern States and Appalachian Mountains.	Similar to black spruce, but cones remain attached to twigs when ripe.
16. Hemlock (<i>Psuga canadensis</i>).	Northern and Eastern States.	Leaves ½ to ¾ inch long, attached by tiny leaf-stalks; cones ½ to ¾ inch long.
17. Bald cypress (Southern cypress) (<i>Taxodium distichum</i>).	South Atlantic and Gulf States in swamps.	Leaves ½ to ¾ inch long, falling off in winter; cones bell-like.
18. Balsam fir (<i>Abies balsamea</i>)..	Northeastern States to southwest Virginia.	Leaves ½ to 1½ inches long; cones falling to pieces when ripe.
19. Fraser fir (<i>Abies balsamea</i>)..	High southern Appalachian Mountains.	Similar to balsam fir, except cones which are "scale-covered."
20. Arborvitæ (<i>Thuja occidentalis</i>).	Northeastern States.....	Leaves scale-like; cones ½ to ¾ inch long, bent backward on twigs.
21. White cedar (<i>Chamæcyparis thyoides</i>).	Swamps of eastern and Gulf Coast.	Cones ball-like, leaves resembling arborvitæ.
22. Red cedar or juniper (<i>Juniperus virginiana</i>).	Eastern United States.....	Leaves scale-like, those on young shoots and seedlings awl-shaped; cones changed into a soft berry.
23. Sweet gum (Red gum) (<i>Liquidambar styraciflua</i>).	Southeastern States.....	Leaves star-shape, fruit a bur-like ball suspended by a long stalk.
24. Sycamore or Buttonwood (<i>Platanus occidentalis</i>).	Eastern United States.....	Leaves broad and coarsely toothed; base of leafstalk inclosing winter bud in peculiar manner; fruit a hard surfaced, long-stalked ball.
25. White oak (<i>Quercus alba</i>)....	do.....	Leaves deeply lobed, not bristle-tipped; acorns ripening in one season.
26. Bur oak (<i>Quercus macrocarpa</i>).	Northeastern United States, Wyoming.	A white oak with fringe-edged acorn and leaves more deeply lobed toward their base.
27. Overcup oak (<i>Quercus lyrata</i>)..	Southeastern United States...	A white oak with acorns completely or almost covered by the acorn cup.
28. Post oak (Box oak) (<i>Quercus minor</i>).	Eastern United States.....	A white oak with leaves cut deeply above and below the middle lobes, forming the suggestion of a cross.
29. Chestnut oak (<i>Quercus prinus</i>).	Northeastern States and Appalachian Mountains. Common on ridges.	A white oak with leaves resembling those of the chestnut.
30. Red oak (<i>Quercus rubra</i>)....	Eastern United States.....	Leaves deeply cut, with bristle-tipped points; acorns ripening in 2 seasons, with acorn cups very shallow.
31. Black oak (<i>Quercus velutina</i>)..	do.....	A red oak with thicker leaves which are minutely woolly beneath; acorns with cups as deep or deeper than wide.
32. Pin oak (<i>Quercus palustris</i>)..	do.....	A red oak with smaller leaves and smaller and shallower cupped acorns.
33. Southern Red or Spanish Oak (<i>Quercus digitata</i> , <i>Quercus falcata</i>).	Central and Southeastern States.	A red oak with leaves very deeply cut, the upper central portion being very narrow and sometimes slightly curved. Abundant.
34. Water oak (<i>Quercus nigra</i>)...	Southeastern United States...	Leaves not toothed, with large terminal lobe, sometimes 3-lobed. Acorns with shallow cup. Much planted as street tree throughout South.
35. Willow oak (<i>Quercus phellos</i>)..	Eastern United States.....	A red oak with leaves not toothed nor lobed; but resembling a smooth-edged willow or peach leaf. Much planted as street shade tree in Southern States.
36. Live oak (<i>Quercus virginiana</i>).	Southern States.....	An evergreen oak with leaves not toothed nor notched; acorns with long stalks.

ONE HUNDRED IMPORTANT FOREST TREES—Continued.

Name.	Distribution.	Remarks.
37. Basswood or Linden (<i>Tilia americana</i>).	Eastern United States.....	Leaves broadly heart-shaped with finely toothed edge; fruit a cluster of little woody balls suspended from the middle of a long narrow leaf.
38. White basswood (<i>Tilia heterophylla</i>).	Middle and South Atlantic States.	Similar to basswood excepting that the leaves are whitish or minutely woolly beneath.
39. Hackberry (Sugarberry) (<i>Celtis occidentalis</i>).	Eastern United States and west to New Mexico and Oregon.	Leaves finely toothed; long pointed; fruit a long stalked, single-seeded berry with very thin flesh.
40. Whiteelm (<i>Ulmus americanus</i>).	Eastern United States.....	Leaves sharply toothed; fruit flat, papery, about $\frac{1}{2}$ inch long, fringed around with tiny hairs.
41. Slippery elm (<i>Ulmus fulva</i> , <i>Ulmus pubescens</i>).	do.....	Similar to white elm, but inner bark is slippery and the flat fruits have a smooth edge.
42. Cork elm (<i>Ulmus racemosa</i>).	do.....	Differing from other elms in having fruit minutely hairy all over, not merely around edges. Twigs with corky ridges.
43. Holly (<i>Ilex opaca</i>).	do.....	Evergreen tree with leaves with large spiny teeth, and fruit a bright red berry remaining attached through the winter. Small tree.
44. Beech (<i>Fagus americana</i> , <i>Fagus atropunica</i>).	do.....	Leaves with saw-tooth edge; fruit a light brown nut, ripening and falling from spine covered hull in late summer.
45. Chestnut (<i>Castanea dentata</i>).	Northeastern and middle Atlantic States.	Leaves with sharp, forward pointing teeth; fruit, a cluster of nuts surrounded with a very spiny hull. A plant disease is rapidly killing chestnut timber.
46. Chinquapin (<i>Castanea pumila</i>).	Middle and Southern States...	Leaves smaller than chestnut and finely woolly beneath; but one nut in the spiny husk. Mostly known as a shrub but reaches tree size.
47. Black willow (<i>Salix nigra</i>).	Eastern United States.....	Leaves slender, long pointed, and finely toothed. The largest of our willows, difficult to distinguish from dozens of other kinds of willow.
48. Balm of Gilead (Balsam poplar) (<i>Populus balsamifera</i>).	Northern United States.....	Leaves very broad at base, toothed, with round leafstalk.
49. Cottonwood (Carolina poplar) (<i>Populus deltoides</i>).	Eastern United States.....	Leaves resembling Balm of Gilead, but with flattened leafstalk.
50. Swamp cottonwood (<i>Populus heterophylla</i>).	South Atlantic and Gulf States.	Leaves with round leafstalk minutely woolly on underside when young.
51. Aspen ("popple") (<i>Populus tremuloides</i>).	Northern and Western United States.	Leaves broad, finely toothed, leafstalks flat, longer than blades.
52. Big-toothed aspen (<i>Populus grandidentata</i>).	Northeastern United States...	Leaves broad, coarsely toothed, with flattened leafstalks.
53. Paper birch (<i>Betula papyrifera</i>).	Northern United States.....	Leaves broad at base, finely toothed, fruit a papery cone which falls apart when ripe, bark peeling off in thin sheets.
54. Sweet birch (<i>Betula lenta</i>).	Northeastern United States...	Bark dark brown, hard and close, not peeling off in sheets, tiny scales of cones smooth, not minutely hairy along edges as in yellow birch.
55. Yellow birch (<i>Betula lutea</i>).	Eastern United States.....	Bark yellow gray, tiny scales of the cones minutely hairy along edges.
56. Red mulberry (<i>Morus rubra</i>).	do.....	Leaves heart-shaped, sharply toothed. Fruit red or black. The white mulberry comes from Asia.
57. Wild plum (<i>Prunus americana</i>).	do.....	Leaves pointed, finely toothed, fruit red or yellow with short stalks. Branches somewhat spiny. Calyxlobes of flowers with smooth edge. Small tree or shrub.
58. Wild red cherry (<i>Prunus pennsylvanica</i>).	do.....	Fruit bright red when ripe, long stalked in clusters of 3 to 5.
59. Choke cherry (<i>Prunus virginiana</i>).	do.....	Fruit in a long cluster, ripe berries mostly at base, no remains of flower persisting.
60. Wild black cherry (<i>Prunus serotina</i>).	do.....	Fruit resembles choke cherry, but with remains of flower attached to base of the cherries.
61. Yellow or tulip poplar (<i>Liriodendron tulipifera</i>).	do.....	Leaves large, blunt or with deep notch at end; flowers large; yellow, fruit a woody cone.
62. Sassafras (<i>Sassafras sassafras</i>).	do.....	Leaves oval, with one lobe like a "mitten," or with a lobe on each side. Twigs fragrant.

ONE HUNDRED IMPORTANT FOREST TREES—Continued.

Name.	Distribution.	Remarks.
63. Black gum (Pepperidge) (<i>Nyssa sylvatica</i>).	Eastern United States.....	Leaves oval with smooth edge. Fruit, an elongated berry with seed but little flattened and stone scarcely ridged.
64. Water gum (<i>Nyssa biflora</i>)...	Southern States.....	Resembling black gum, but fruit which also grows in pairs, has a flattened and ridged stone.
65. Tupelo gum (<i>Nyssa aquatica</i>). Known also as cotton gum. Associated with cypress.	Swamps of Southeastern Coastal States.	Fruits produced singly, with a stalk longer than the fruit; stone of fruit sharp-edged or winged.
66. Gopher plum (<i>Nyssa ogeche</i>).	Swamps, South Carolina to Florida.	Resembling Tupelo gum, but fruits with stalks shorter than the fruit itself.
67. Sweet magnolia (<i>Magnolia virginiana</i> , <i>Magnolia glauca</i>). Known also as Sweet Bay.	Coastal swamps, Eastern and Gulf States.	Flowers white. Leaves white, silky beneath.
68. Cucumber tree (<i>Magnolia acuminata</i>).	Eastern United States.....	Flowers greenish-yellow. Fruit slender.
69. Umbrella tree (<i>Magnolia fraseri</i>).	Southeastern States.....	Flowers white, leaves deeply lobed at base, forming "ears," green on under side.
70. Large-leaf magnolia (<i>Magnolia macrophylla</i>).	do.....	Flowers white, leaves very large, with "ears" at base, and white beneath. Largest leaved tree in North America (20 to 30 inches long).
71. Persimmon (<i>Diospyros virginiana</i>).	Eastern United States.....	Leaves oval, smooth, with smooth margin, fruit orange colored, 1 to 1½ inches in diameter, edible in late fall.
72. Redbud (Judas tree) (<i>Cercis canadensis</i>).	do.....	Leaves heart-shaped, smooth margin; fruit a pea-like pod in clusters of 4 to 8; flowers resembling a small rose-colored sweet pea.
73. Osage orange (Bois d'arc) (<i>Toxylon pomiferum</i>).	Native to Arkansas, eastern Oklahoma and Texas, but widely planted throughout eastern United States.	Leaves with smooth edges. Fruit a heavy ball 4 to 5 inches in diameter.
74. Sugar maple (<i>Acer saccharum</i>)	Eastern United States.....	Leaves 3 to 5 lobed with large rounded teeth; fruit a pair of keys ripening in autumn.
75. Silver maple (<i>Acer saccharinum</i>).	do.....	Leaves deeply 5-lobed, with sharp irregular teeth; fruit ripening in spring before appearance of leaves.
76. Red maple (<i>Acer rubrum</i>)...	do.....	Leaves 3 to 5 lobed, finely toothed; fruit ripening in spring or early summer.
77. Box elder or ash-leaved maple (<i>Acer negundo</i>).	Throughout United States....	Leaves compound, the leaflets toothed; fruit ripening in early summer.
78. Hardy catalpa (Indian cigar) (<i>Catalpa speciosa</i>).	South Central States, widely cultivated elsewhere.	Leaves large, heart-shaped; fruit a long "pod" filled with flat seeds which are tufted at each end. A better shaped tree than common catalpa (<i>Catalpa baltica</i>).
79. Flowering dogwood (<i>Cornus florida</i>).	Eastern United States.....	Leaves mostly clustered at ends of branches, with slightly wavy margins; flowers white with four large bracts resembling petals. Leaves opposite.
80. Blue dogwood (<i>Cornus alternifolia</i>).	Northeastern States and Appalachian Mountains.	Leaves resembling those of flowering dogwood, but alternate in arrangement; flowers without the four large petal-like bracts.
81. Honey locust (<i>Gleditsia triacanthos</i>).	Central States and Minnesota to Texas. Widely cultivated elsewhere.	Leaves doubly-compound, the leaflets with slightly wavy margins; fruit a pod a foot or more in length, twisted when dry. Trees with large branching thorns.
82. Black locust (Yellow locust) (<i>Robinia pseudacacia</i>).	Appalachian region, widely cultivated and naturalized all over United States.	Leaves compound, leaflets with smooth margins; fruit a pod 3 to 4 inches long. Trees with pairs of short thorns at the base of leaves and twigs. Wood heavy and durable in the ground.
83. Kentucky coffee tree (<i>Gymnocladus dioica</i>).	Ohio and Mississippi valley...	Leaves doubly compound, the leaflets with entire margins; fruit a large wide pod, 6 to 10 inches long, 1½ to 2 inches wide. Trees without thorns.
84. Pecan (<i>Hicoria pecan</i>).....	Mississippi Valley.....	Bud scales few, shell of nut thin and brittle, with large cavities; nuts elongated with sweet kernel.
85. Bitternut hickory (<i>Hicoria minima</i>).	Eastern United States.....	Nut broader than long, with bitter kernel.

ONE HUNDRED IMPORTANT FOREST TREES—Continued.

Name.	Distribution.	Remarks.
86. Water hickory (<i>Hicoria aquatica</i>).	Gulf States and lower Mississippi Valley.	Nut broad, with bitter kernel.
87. Shagbark hickory (<i>Hicoria ovata</i>).	Eastern United States.....	Buds with many scales (all of the preceding hickories have buds with few scales), nuts not flanged at joints, shell thick and bony. Bark loosening from trees.
88. Shellbark hickory (<i>Hicoria laciniosa</i>).	do.....	Difficult to distinguish from shagbark hickory. Twigs are pale orange, while in the preceding they are light red-brown.
89. Mockernut hickory (<i>Hicoria alba</i>).	do.....	Bud scales many, bark closely furrowed not separating from the trunk. Nut oblong.
90. Pignut hickory (<i>Hicoria glabra</i>).	Southern States.....	Like preceding in many respects* Nuts not elongated.
91. Black walnut (<i>Juglans nigra</i>).	Eastern United States.....	Leaves compound, with toothed edges fruit growing singly or in pairs rounded; bark brown.
92. Butternut or white walnut (<i>Juglans cinerea</i>).	do.....	Leaves compound, with toothed edges; fruit in hanging clusters of 3 to 5, pointed and elongated. Velvety cushion just above leaf-scar; bark gray.
93. White ash (<i>Frazinus americana</i>).	do.....	All species of ash are difficult to identify, and mostly require expert knowledge of the fruit or "keys." White ash has a key or fruit with a plump well rounded body and a wing extending almost entirely from the end.
94. Red ash (<i>Frazinus pennsylvanica</i>).	do.....	Differs from white ash in having young twigs velvety and wing of seed extending down along sides of seed-body.
95. Green ash (<i>Frazinus lanceolata</i>).	do.....	Like the preceding, except twigs are smooth.
96. Pumpkin ash (<i>Frazinus profunda</i>).	Southern States.....	Resembling red ash, but fruits are very much larger, sometimes twice the size.
97. Black ash (<i>Frazinus nigra</i>).	Northern and Lake States....	Fruits with a flat wide wing, which extends conspicuously down the sides of the seed body.
98. Water ash (<i>Frazinus caroliniana</i>).	Southeastern States.....	Fruits very wide and flat, frequently 3-winged.
99. Ohio Buckeye (<i>Æsculus glabra</i>).	Ohio and Mississippi Valleys..	Leaves palmately compound; fruit in a knobby husk.
100. Yellow Buckeye (<i>Æsculus octandra</i>).	do.....	Resembling preceding, but fruit in a smooth husk.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 864

Contribution from the Bureau of Markets
GEORGE LIVINGSTON, Chief



Washington, D. C.

PROFESSIONAL PAPER

July 28, 1920

A PEACH-SIZING MACHINE.

By MANLEY STOCKTON, *Investigator in Marketing*, and J. F. BARGHAUSEN, *Investigator in Agricultural Technology*.

The sizing machine described in this bulletin was developed to meet a demand from peach growers for a simple and efficient machine that would accurately and carefully size and distribute peaches to the packing bins. In addition to those features which are always highly desirable in sizing machines, such as sufficient capacity for economical operation, substantial construction, and freedom from delicate adjustments, it was necessary to produce at a reasonable cost (the estimated cost of building single machines at the present price of materials should not exceed \$450), a machine which would not injure tender fruit by bruising or roughening the pubescence. Several sizers were in use in the northern and southern sections when the first experimental machine was built and put in the field, but existing types were open to the general objection that they were too expensive for the smaller grower or, if relatively inexpensive, either were not accurate enough or handled the fruit too roughly.

While the sizer described herein (see fig. 1) was developed primarily to meet the needs peculiar to the packing of peaches in 6-basket carriers, it may also be used, with a few slight changes in the bin construction, for jumble packing of bushel baskets. Furthermore, although the bureau does not officially indorse its use for sizing other crops, it is believed that this machine may be adapted to the sizing of other fruits, such as pears and apples. Where barrel packs are used for apples and no necessity exists for sizing the crop into numerous exact size classes, as is the case in box packing, this machine could probably be used with as good results as any other machine which sizes the fruit by measurement.

CONSTRUCTION.

In designing this machine an effort was made to specify as many standard parts as possible in order to facilitate construction. In the conveyer section (fig. 2) the wood framework is simply made and

serves as a structure to carry the roller sorting conveyer. The conveyer is made by joining a series of wood rollers to a standard drive chain made of alternate D-5 and plain No. 45 links. The roller conveyer is carried up an incline of 23° , as illustrated in figure 1. This slope may be reduced by lengthening the belt, but the conveyer can not be operated successfully if it is made steeper, as some of the larger fruit would be bruised by rolling back. The rollers are $2\frac{1}{4}$ inches in diameter and each is reamed out at both ends to receive the pins on the D-5 links in the drive chains. The hopper or feed, which is heavily padded and sloped slightly to permit the fruit to roll to the

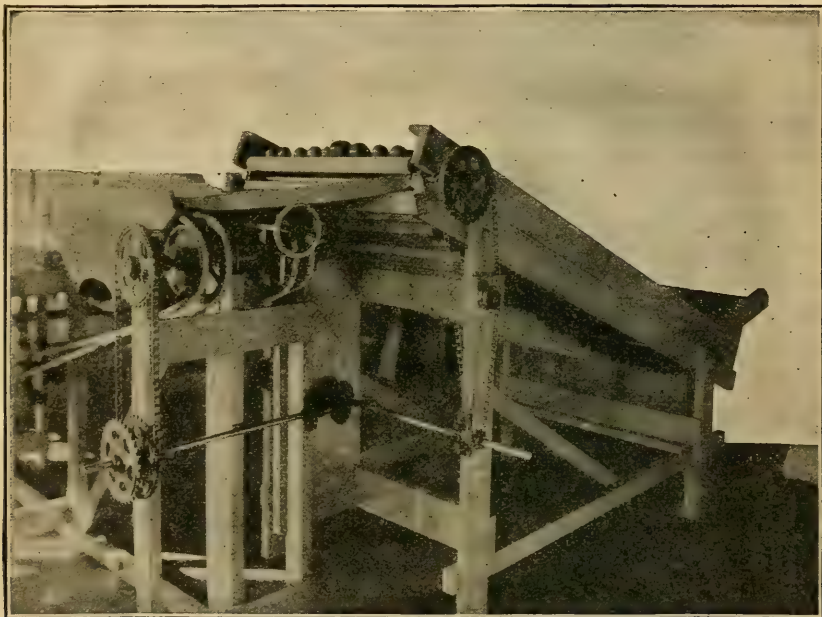


FIG. 1.—In order to make the machine more compact the sorting conveyer is joined to the sizer section at right angles. Note the continuous bins and packing bench and also the tracks which carry the ropes. The galvanized iron distributors seen at the ends of the ropes are used to divert the fruit to all parts of the end bin.

sorting conveyer, holds from a half bushel to a bushel of peaches. Some sort of chute should be attached to the sides of this conveyer at about halfway up the incline in order to provide a convenient means for the disposal of defective fruit by the sorters.

Figure 3 shows a cross section of the sizing mechanism and bins. Rope sizers resembling this one in a general way have been in use to a limited extent for many years. This machine is an improvement over others of the same type, because the tracks carrying the sizing ropes can be adjusted easily and quickly to any desired width while the machine is in operation by the device shown in figures 4 and 5 and also because the ropes are joined by a coupling which obviates the use of a

cumbersome splice. The crop is sized and distributed to packing bins having adequate space to accommodate ten to fifteen packers, who normally can pack the fruit fast enough to keep up with the work when the machine is running at full capacity.

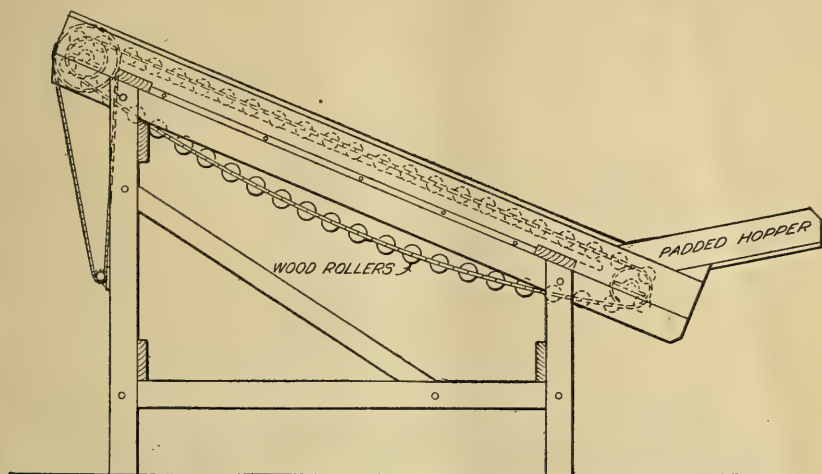


FIG. 2.—Side view of conveyer.

The tracks are supported by overhead iron braces attached to the central structure of the sizing section in such a way that the peaches have an unobstructed path in dropping through to the packing bins. The tracks in which the ropes travel are made of straight-grained white pine and are grooved out, as illustrated, to carry the ropes and to

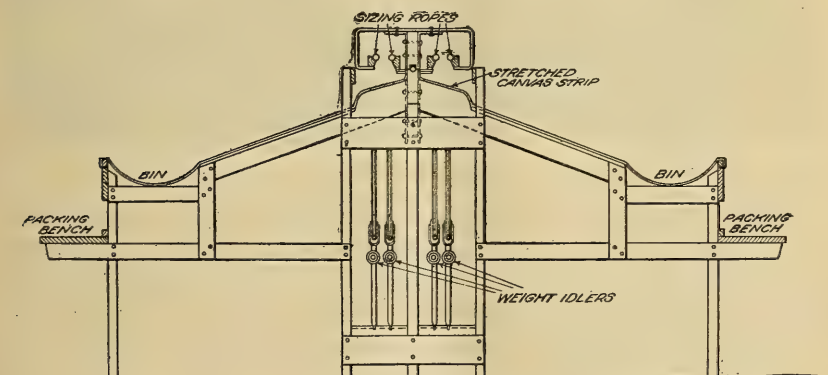


FIG. 3.—Cross-section view.

keep them accurately lined and exactly spaced throughout their length. The ropes are $\frac{3}{4}$ -inch 3-strand cotton rope and are very flexible. This flexibility makes it easier to keep the rope in the grooves. The ropes are also held in the grooved tracks by the tension produced by weight idlers under the machine. A piece of stretched

canvas extends the length of the machine immediately under the opening between the tracks, to receive the fruit from the ropes and break the fall into the sloping bins. This strip is fastened to a ratchet drum at one end by which it may be tightened. The bins (see fig. 1), which slope about 20° , are in two parts; the sloping floor is heavily padded and the bin pockets are formed by the loose canvas at the bottom, from which the fruit is taken by the packers.

OPERATION.

The peaches from the field are placed in the feeding hopper and fed in regular amounts into the spaces between the rollers as they are

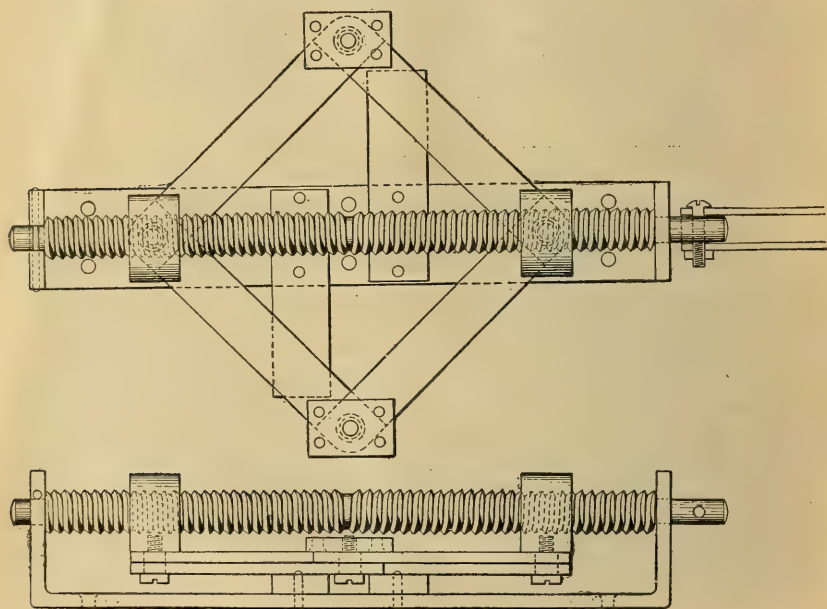


FIG. 4.—Detail of screw-controlled track adjuster.

presented. The rollers revolve as they travel up the incline, thus revolving the peaches which rest on them as they pass before the sorters. This is a great aid to sorting, for it makes unnecessary the turning of the fruit by hand in order to see the entire surface and therefore makes it possible for more efficient work to be done by fewer people than is the case where an endless canvas belt or an inclined chute is used for this purpose.

The sorters remove the defective specimens not intended for packing and place them in baskets or chutes attached to the sides of the conveyer frame. When the peaches reach the upper end of the conveyer they are delivered to a divided galvanized-iron chute that directs half of the fruit to one set of sizing ropes and half to the other.

The ropes at this end of the machine are parallel and remain so for the first 3 feet. They are spaced to permit all fruit too small for packing to drop through into a canvas chute which delivers it into a basket or bin. After the first 3 feet the ropes begin to diverge and continue to do so till they reach the far end of the machine. The amount of divergence of the ropes is governed by the sizes desired in the bins. When the sizes are uniform and an equal distribution is desired to all bins the divergence will be less per foot than if there were a wide variation in the sizes of the fruit passing over the ropes. One of each pair of ropes travels slightly faster than the other, which tends to

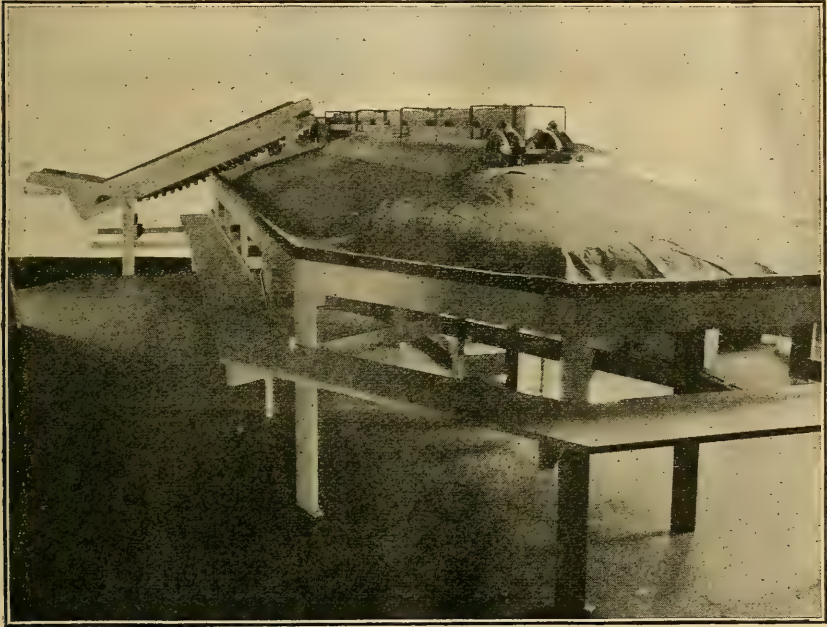


FIG. 5.—View showing the driving pulleys, the track-adjusting wheel, and the galvanized iron chute used to distribute the fruit from the roller-sorting conveyer to the sizing unit.

cause the peaches to straighten out lengthwise on the ropes, so that the transverse diameter is subjected to measurement. Very few peaches ever get on the ropes crosswise, as the V-shaped trough which extends for the first 3 feet serves to straighten them out. Thus the peaches are sized on the basis of their minimum transverse diameter.

The largest peaches go over the end of the ropes and pass over galvanized-iron adjustable chutes (see fig. 1), which facilitate the distribution of the fruit to all parts of the end bin. The size of the fruit which passes into the end bin is, of course, regulated by the wheel-and-lever adjusters at the end of the machine.

The sloping bins are without partitions, so that the packers are free to station themselves at any place where fruit of the desired size is to be found. The range of size at any point furnishes the packer with the slight variation that customarily appears between the fruit in the top and in the bottom of the baskets in packing the 6-basket carrier.

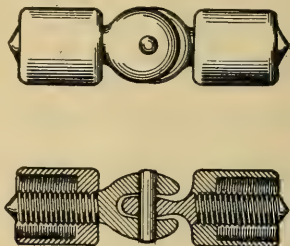


FIG. 6.

If the grower wishes to pack bushels or hampers, and does not wish to arrange each individual specimen in the container, he can alter the bins slightly and run the peaches into the shipping package in the usual jumble pack.

NOTE.—A set of nine working drawings for this machine may be secured from the Bureau of Markets for \$2. Letters of patent No. 1,338,276 have been issued on this machine to Mr. J. F. Barghausen, of the Department of Agriculture. Free use of the invention is dedicated to the people of the United States.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 865

Contribution from the Bureau of Markets
GEORGE LIVINGSTON, Chief



Washington, D. C.



August 16, 1920

A CLASSIFICATION OF LEDGER ACCOUNTS FOR CREAMERIES.

By GEORGE O. KNAPP and BURTON B. MASON, *Assistants in Market Business Practice*,
and A. V. SWARTHOFT, *Investigator in Market Business Practice*.

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INTRODUCTION.

In presenting this "Classification of Ledger Accounts for Creameries" it is the aim of the Bureau of Markets to emphasize the importance of the use of a definite and logical classification of accounts for keeping the financial records of any business and to describe in detail a classification which can be used advantageously by creameries. The use of such a classification is not only a great aid to the bookkeeper in the performance of routine duties, but its consistent use also insures a uniform method of presenting the financial information from year to year regardless of changes in the personnel. The use of these uniform methods by an industry as a whole makes possible the exchange of data regarding business operations, which is of untold value as a guide to efficient operation.

It is felt that the consistent use of the classification described herein will be of great benefit to the entire creamery industry. The explanatory paragraphs will be found helpful in deciding questions arising from a new or unusual transaction, the necessary entries for which may be unknown to the bookkeeper.

In order to open the Ledger accounts for a set of double-entry books, it is necessary to take a physical inventory of all assets and to take into consideration all liabilities of the concern. These items

should be arranged in the form known as a Balance Sheet, with assets on the left and liabilities on the right. (See illustration on p. 34.) The difference between the total assets and total liabilities will represent the net worth, either as capital stock, surplus, deficit, or good will. These accounts are described at length under their respective captions. The assets should be arranged in the order of their probable cash realization and the liabilities in the order of their probable priority as to liquidation. A set of Ledger sheets should be headed with the account captions as shown herein.

The items appearing on the Balance Sheet should then be entered in the Journal,¹ the amount of each item being posted from the Journal to the proper Ledger account. As succeeding transactions are classified, entered in the Journal, and posted to the proper Ledger accounts, the Ledger will contain a summary of the financial facts of the business, arranged under their proper designation, each summary being known in bookkeeping as an account. The various accounts should be classified according to their nature into the following groups, which are defined in order that it may be clearly understood how they differ from one another.

Current Assets are items of cash and those which can be readily converted into cash or its equivalent.

Fixed Assets are those of a permanent nature which are used in conducting the business, such as land, buildings, machinery and equipment.

Prepaid Expense is that which is paid in advance of usage.

Current Liabilities are obligations which are due, or about to become due, or are those which are increasing daily but are not payable until some future date.

Reserve accounts are those by means of which a certain amount is set aside out of the earnings of the company for some specific purpose.

Net Worth accounts are those which represent the ownership, including any accumulated profits or losses of the company.

Income accounts are those through which the revenue of the company is reflected.

Expense accounts are those which reflect the cost of conducting the business. It should be remembered that the cost of conducting the business may not be actually paid in cash during the period in which the expense is incurred.

Index tabs labeled with the above headings will be found convenient in locating the various Ledger accounts.

The necessity of making the complete segregation of accounts shown in the following charts may be questioned by those who have

¹ See U. S. Department of Agriculture Bulletin No. 559, Accounting Records for Country Creameries, by John R. Humphrey and G. A. Nahstoll. 1917.

never recognized an accounting system as a vital assistance to the management. The real purpose of accounting is not only to show the board of directors, or proprietor, that the business has been conducted at a profit or loss, and that no fraud has been committed, but also to present facts concerning the business in such a manner that the management may direct the operations intelligently.

In securing the very best benefits possible from an adequate accounting system, nothing can take the place of an independent audit by a reputable firm of public accountants. Some of the advantages to be derived from such an audit may be summarized as follows:

- (1) An impartial and disinterested opinion of the general policy and administration of the business is secured.
- (2) The financial records are carefully examined, and reports presented in the best possible form.
- (3) Opinion is rendered as to whether the methods in use could be improved and whether or not adequate reserves are being accumulated to care for depreciation, bad accounts, etc.

The cost of such an audit may seem prohibitive to some of the smaller organizations. However, this expense may be somewhat reduced by the formation of a cooperative auditing association, such as is now in existence in some sections of the country. It is strongly recommended that an audit of the kind referred to above should be made at the close of the fiscal year.

Probably some organizations will not require all of the accounts shown in this classification. For instance, in a creamery holding no notes, neither the Notes Receivable account nor the Notes Receivable Discounted accounts would be used. Also, in small concerns it might be unnecessary to carry separate accounts for factory labor and office salaries, and other similar items. Some organizations may require additional accounts. The discussion in this bulletin should enable any creamery bookkeeper to set up intelligently a complete set of accounts.

By comparison with U. S. Department of Agriculture Bulletin No. 559, it will be noted that some of the procedure outlined therein differs from that described in this publication. These changes have been found desirable after observation of actual operations extending over a period of several years.

CHART OF LEDGER ACCOUNTS.

BALANCE SHEET ACCOUNTS (NOS. A TO I, INCLUSIVE).

ASSETS.

Account No.		Page.
A.	Current Assets:	
A 1.	Cash on Hand.....	5
A 2.	Bank Account (name of bank).....	6
A 3.	Notes Receivable.....	6
A 4.	Accounts Receivable Control.....	7
A 5.	Patrons Accounts Receivable.....	7
A 6.	Manufactured Products Inventory.....	7
A 7.	Operating Supplies Inventory.....	8
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C 3.	Machinery and Equipment.....	10
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ASSETS.

A. CURRENT ASSETS.

CASH ON HAND (A 1).

DEBIT.	CREDIT.
1. With the total of undeposited checks and cash as shown by Balance Sheet at the time of opening the books.	1. With the total of undeposited checks and cash at the beginning of the period.
2. With the total of undeposited checks and cash at the close of the period.	

In order that a complete Trial Balance may be taken from the Ledger, without consideration of unposted items in any book of original entry, it is desirable that a Cash on Hand account be opened and maintained in the Ledger. Into this account is posted the amount of actual cash in the office at the time of opening the books and at the close of each accounting period. At the beginning of the following period, this

amount should be entered as the first item in the Cash Journal, the debit being entered in the Cash column, the credit in the General Ledger column, from which it is posted to this account.

It is always desirable that all cash receipts be deposited during the accounting period in which they are received, and that all disbursements be made by check. Often, however, small items are paid in cash. Such expenditures should be covered by an order, which is approved by the manager, showing the amount, the date, account chargeable, and any other necessary information, and should be signed by the payee. At the end of each period a check should be drawn for an amount equal to the disbursements. The charge for this check should be made in the Cash Journal to the various Expense accounts and the check must be included in the next bank deposit.

BANK ACCOUNT (A 2).

(Name of bank.)

DEBIT:

1. With the balance in the bank as shown by the Balance Sheet at the time of opening the books.
2. With the total of all deposits during the period.
3. With interest credited by the bank.

CREDIT:

1. With the amount of overdraft as shown by the Balance Sheet at the time of opening the books.
2. With the total of all amounts disbursed by check during the period.
3. With interest charged by the bank on overdraft.

This account will appear in the Ledger under the name of the bank and should be debited with the amount of cash on deposit at the beginning of the period. This balance is determined by taking the balance rendered by the bank and deducting therefrom the total of all outstanding or uncanceled checks. Normally the balance shown by the bank will be in excess of that shown by the organization.

Debits and credits to this account for interest receipts and payments, and exchange charges will arise from debit and credit memoranda submitted by the bank at the time of rendering its statement.

NOTES RECEIVABLE (A 3).

DEBIT:

1. With the face value of notes of others on hand as shown by the Balance Sheet at the time of opening the books.
2. With the face value of the notes received during the period.

CREDIT:

1. With amounts paid on notes by their makers, settlements made in any other manner or amounts charged Loss and Gain as uncollectable.

When notes are taken in payment for subscription to capital stock the total amount of such notes should be debited to this account. When notes are discounted at the bank, their face value, less the discount charged, should be debited to the Bank Account. This, however, does not change the notes, there being a contraliability to the bank for the full face value of the notes discounted. This liability is further discussed under Notes Receivable Discounted.

ACCOUNTS RECEIVABLE CONTROL (A 4).

DEBIT:

1. With the total amount charged to customers' individual account as shown by the Balance Sheet at the time of opening the books.
2. At the close of the period with the total of all sales charged to customers' accounts during the period.

CREDIT:

1. At the close of the period with the total amount received from customers on account.
2. With any other credits to customers' accounts, including the writing off of doubtful accounts.

Inasmuch as the total of all charges and credits applying to the customers' individual accounts constitute the entries to the above account, it is apparent that this account is a control over the customers' individual accounts. It should in all cases be made to agree with the total of the individual accounts before a Trial Balance is taken. The balance, which is the total amount due from customers, must equal the net total of the balance of the individual amounts.

PATRONS' ACCOUNTS RECEIVABLE (A 5).

DEBIT:

1. With the amount of any purchase by patrons during the period.

CREDIT:

1. With any payments on account by patrons.
2. With any deductions from patrons' vouchers at the time of making settlement.

This is a control account for sales to patrons, and should be operated in a manner similar to Accounts Receivable Control, all sales being posted to accounts from the sale slip, and the total of these sales being entered in this account from the Journal.

It may happen that a patron who has furnished only a small amount of butter fat during the period will have purchased from the creamery more than his voucher will cover. The voucher, however, should be fully made out, showing all amounts to the patron's credit and the charges against him, together with the balance due the creamery. The balance on this account, together with the amount of any new purchases, should be deducted from the next vouchers, or the patron required to make payment in full.

MANUFACTURED PRODUCTS INVENTORY (A 6).

DEBIT:

1. With the value of all manufactured products (and merchandise) on hand as shown by the Balance Sheet at the time of opening the books.
2. With the value of all manufactured products (and merchandise) on hand at the close of the fiscal period.

CREDIT:

1. Immediately after the beginning of a new period with the balance of this account.

It is not intended to carry the inventory of manufactured products currently in the Ledger, although at the time of opening the books it is necessary to show this amount in order to arrive at a true basis of the net worth of the organization. The inventory should include products on hand, and any which may have been shipped on consignment and not paid for by the consignee. If part payment has been made on consigned goods, the amount of this payment should be deducted from the inventory.

Under cooperative methods of conducting a creamery, distribution is made to patrons for all butter, or other product, actually manufactured during a period, whether or not it has all been sold. This necessitates a slightly different accounting for inventories of manufactured products than is used under the ordinary plan of business operations, the amount of the inventories being credited to Sales accounts at the end of the fiscal period, and charged to these accounts at the beginning of a new period, instead of these entries being made in the Purchases accounts. The following Journal entries will illustrate:

COOPERATIVE CREAMERY.		
DEBIT.		CREDIT.
\$350	Manufactured Products Inventory.	
	Butter Sales.....	\$350

To place inventory on books at end of fiscal period before closing books:

DEBIT.		CREDIT.
\$350	Butter Sales.	
	Butter Inventory.....	\$350

To close Butter Inventory account at the beginning of the new fiscal period.

PRIVATE CREAMERY.		
DEBIT.		CREDIT.
\$350	Manufactured Products Inventory.	
	Butter Fat Purchases.....	\$350

To place inventory on the books at the end of the fiscal period before closing the books.

DEBIT.		CREDIT.
\$350	Butter Fat Purchases.	
	Manufactured Products Inventory.....	\$350

To close inventory account at the beginning of the new fiscal period.

OPERATING SUPPLIES INVENTORY (A7).

DEBIT:

1. With the cost of all operating supplies on hand as shown by the Balance Sheet at the time of opening the books.
2. With the cost of all operating supplies purchased.
3. With all freight, express, and drayage charges on operating supplies.

CREDIT:

1. At the close of the period with the cost of all operating supplies used during the period.
2. With the cost of all supplies sold or disposed of in any other manner.

Operating Supplies include such items as fuel, oils and greases, packages and liners, butter color, salt, glassware, acid, washing powder, etc.

An Inventory Report (see U. S. Department of Agriculture Bulletin No. 559, p. 11) should be kept at all times. The balance on this report must agree with the balance on this account.

By reference to the descriptions of the Operating Expense accounts (Nos. M2 and M3) it is easy to determine what account should be charged with the supplies used.

B. SECURITIES.
SINKING FUND (B1).

DEBIT:

1. With all amounts withdrawn from the general funds of the business and deposited in a special fund for the specific purpose of meeting some fixed obligation at a future time.
2. With any income derived from the money in this fund. (Credit Sinking Fund Reserve.)

CREDIT:

1. With any amount expended for the purpose for which the special fund was created.

A sinking fund is an amount of money periodically withdrawn from the business and invested in securities or deposited in a separate bank account for the purpose of meeting a fixed liability at some future time. For the purpose of determining the amount to be set aside each period, reference may be made to any of the published bond tables.

Further discussion of this subject will be found under Sinking Fund Reserve, page 19.

C. FIXED ASSETS.
LAND (C1).

DEBIT:

1. With the original purchase price of land as shown by the Balance Sheet at the time of opening the books.
2. With all costs pertaining to the original purchase.
3. With the cost of any permanent improvement made subsequent to the purchase.

CREDIT:

1. With the total book value of any land sold.

Land should be carried on the books at actual costs and should not be increased or decreased because of a change in value. The difference between the selling price and the original cost of any real estate should be debited or credited, as the case may be, to Surplus Adjustment account.

BUILDINGS (C2).

DEBIT:

1. With the original purchase price of the buildings as shown by the Balance Sheet at the time of opening the books.
2. With costs of all new construction.
3. With the cost of all additions or alterations when such costs increase the usefulness of the plant.
4. With the excess of the cost of the replacement over the original cost of the part replaced.

CREDIT:

1. At the time of sale or destruction with the total book value of any building sold or destroyed.

As the land and buildings are frequently purchased at the same time, the purchase price will include both assets. Care must be exercised that a proper division of these assets is made as depreciation is to be figured only upon the buildings.

MACHINERY AND EQUIPMENT (C3).

DEBIT:	CREDIT:
1. With the cost of all the machinery as shown by the Balance Sheet at the time of opening the books.	1. With the total book value of any machinery and equipment that is sold or discarded.
2. With the cost of additions or alterations provided the efficiency is materially increased.	
3. With freight, express, and drayage charges on any purchase.	
4. With cost of installation.	

This account should be charged with the costs of all items of machinery and equipment, which, under ordinary circumstances, will last three years or more, such as engines, boilers, motors, etc. When any article which has been charged to this account is to be replaced, the asset account should be credited with the cost value placed on this item at the time of opening the books or at the time of subsequent purchase. Example: A piece of machinery costing \$100 was replaced by a new one costing \$150, cash being paid for the new article. The Journal entry would be made as follows:

DEBIT.	CREDIT.
\$100	Reserve for Depreciation on Machinery and Equipment.
	Machinery and Equipment..... \$100
	(For discarded machine costing \$100.)
150	Machinery and Equipment.
	Bank Account..... 150
	(For purchase of new machine.)

To the invoice value of any machinery purchased should be added any expense incurred, such as freight or installation charges. In case the amount set aside as Reserve for Depreciation on Plant is not sufficient to cover the original cost of the item replaced, the loss sustained should be charged to an account specifically captioned. Example: A boiler costing \$150 was completely destroyed by an explosion. At the time the account Reserve for Depreciation on Machinery and Equipment shows a credit balance of \$100. It was necessary to pay \$200 for a similar boiler. The following Journal entries should be made:

DEBIT.	CREDIT.
\$50	Reserve for Depreciation on Machinery and Equipment.
100	Loss, boiler explosion.
	Machinery and Equipment..... \$150
	(For loss on Machinery and Equipment on account of explosion.)
200	Machinery and Equipment.
	Bank account..... 200
	(For purchase of new boiler.)

In the above entries it should be carefully noted that the full amount set aside as a Reserve for Depreciation on Machinery and equipment has not been entirely exhausted by this loss, inasmuch as this fund is set aside to cover depreciation on all the machinery and equipment, and only the relative proportion applying to the boiler can be charged to the reserve account.

The account, Loss, boiler explosion, should be periodically reduced by the following entry:

DEBIT.	CREDIT.
\$10 Expense, boiler explosion.	
	Loss, boiler explosion..... \$10
	(For periodical charge to amortize loss result- ing from explosion.)

At the close of the fiscal year the account Expense, boiler explosion, should be carried to Loss and Gain account.

TOOLS (C 4).

DEBIT:	CREDIT:
1. With the estimated value of all the small tools as shown by the Balance Sheet at the time of opening the books.	1. With the book value of any tool sold and not replaced.

This account should include such articles as hammers, wrenches, and small hand tools, which will under ordinary circumstances last for a period of less than three years. Further discussion of this subject will be found under Tool Replacement. The supply of tools on hand should be inventoried at least once each year, and any large variation from this account should be adjusted.

MOTOR VEHICLES (C 5).

DEBIT:	CREDIT:
1. With the cost of any trucks as shown by the Balance Sheet at the time of opening the books.	1. With the book value of trucks disposed of or destroyed.
2. With the purchase price of new trucks.	

OFFICE FURNITURE AND EQUIPMENT (C 6).

DEBIT:	CREDIT:
1. With the total costs as shown by the Balance Sheet at the time of opening the books.	1. With the book value of any article sold, discarded, or destroyed.
2. With additional purchases.	
3. With freight, express, or drayage charges incident to purchase.	
4. With cost of installation.	

This account should include such articles as desks, filing cases, adding machines, typewriters, ledger, journal binders, etc., which should last for an indefinite period of time. This equipment should be inventoried every year, and the account adjusted to agree with the actual value.

D. PREPAID EXPENSE.**PREPAID INSURANCE (D 1).**

DEBIT:	CREDIT:
1. With the total amount of fire insurance premiums prepaid as shown by the Balance Sheet at the time of opening the books.	1. At the close of the period with the portion of fire insurance premiums expired.
2. With the amount of fire insurance premiums paid.	2. With the returned premium when any policy is canceled.

Usually policies run for a year and are paid for in advance. This payment is charged to the Prepaid Insurance account and represents an asset value. The amount is reduced periodically by a charge to Insurance Expense, the credit being carried to the Prepaid Insurance account.

PRINTING AND STATIONERY (D 2).

DEBIT:	CREDIT:
1. With the estimated value of the stock on hand as shown by the Balance Sheet at the time of opening the books.	1. At the close of the period with the estimated value of the amount used during the period.
2. With the cost of all purchases during the period.	2. With any amount disposed of otherwise.

It is advisable to carry a Printing and Stationery account, inasmuch as such supplies will be purchased in quantities sufficient to cover several months' usage. Prorating the expense over the period during which it will be used is preferable to burdening the month in which the purchase is made with the entire cost and thus possibly affecting the profits for the period. In this case Printing and Stationery Inventory account will be credited with the value of the amount used, the corresponding debit being carried to Office Supplies.

LIABILITIES, RESERVES, AND NET WORTH.**F. CURRENT LIABILITIES.****NOTES PAYABLE (F 1).**

DEBIT:	CREDIT:
1. With the amounts paid in partial or entire settlement of signed obligations.	1. With the face value of all signed obligations of the organization as shown by the Balance Sheet at the time of opening books.
2. With signed obligations given in renewal.	2. With the face value of any obligations subsequently issued.

Should a note be renewed, thus in effect giving a new note for the old note, debit this account for the face value of the old note, and credit the account with the amount of the new note.

A careful record should be maintained of all notes given, showing date issued, to whom, date of maturity, and rate of interest.

ACCOUNTS PAYABLE (F 2).

DEBIT:

1. With payment on account.
2. With purchased goods returned for credit.
3. With allowances on purchases.
4. With cash discount on purchases.

CREDIT:

1. With amounts due creditors on open accounts at time of opening the books as shown by the Balance Sheet.
2. With the invoice value of merchandise purchased on credit. (Debit the various Inventory or Expense accounts.)

Separate accounts should be opened for firms with which a large credit business is conducted currently. Miscellaneous accounts payable may be handled in one account under the caption Miscellaneous Accounts Payable.

It is not the intention to carry individual Ledger accounts with all the various creditors, owing to the fact that in many cases only a single purchase will be made from one concern and that practically all invoices will be paid during the period. Care must be exercised when entering checks to ascertain whether they should be charged to accounts payable when goods are purchased on credit, or to an inventory or expense account when goods are purchased for cash.

When the invoice has been credited to Accounts Payable, the check given in payment must be charged to Accounts Payable. As the canceled check is a sufficient receipt, it is suggested that invoices be stamped "Paid —————, 19—," and filed alphabetically for future reference.

A method preferable to that just described, especially for larger organizations, is the use of a voucher payable register, description of which may be found in most books on accounting.

ACCOUNTS PAYABLE PATRONS (F 3).

DEBIT:

1. With the amount paid patrons by cash or check.

CREDIT:

1. With the net amount due patrons as shown by the Balance Sheet at the time of opening the books.
2. At the close of the period with the net amount due patrons for deliveries during the period.

The liability to patrons will be closed at the time payment is made by a debit to Accounts Payable Patrons, the corresponding credit being made to Cash or Bank Account.

At the time of opening the books, it may occasionally be impracticable to determine the actual amount due the patrons, but this should be estimated as closely as possible, set up as a liability, and then any difference between the estimated and actual amounts should be charged or credited to Surplus Adjustment account. Example: If the estimated amount were \$1,350 and the actual amount proved to be \$1,410, the Journal entry at the time of payment would be:

DEBIT.

\$1,035 Account Payable Patrons.
 60 Surplus Adjustment account.

CREDIT.

Bank Account..... \$1,410

If the estimated amount was \$1,410 and the actual amount was \$1,350 the entry at the time of payment would be:

DEBIT.		CREDIT.
\$1,410	Account Payable patrons.	
	Surplus Adjustment account.....	\$60
	Bank Account.....	1,350

In both the above cases the Accounts Payable Patrons account would be closed. The Surplus Adjustment account should be closed into Surplus account as described on page 22.

NOTES RECEIVABLE DISCOUNTED (F 4).

DEBIT:	CREDIT:
1. With the face value of notes discounted when settled for either by maker of through payment by the organization to the bank.	1. With the face value of all notes receivable discounted as shown by the Balance Sheet at the time of opening the books.
	2. With the face value of all notes subsequently discounted.

By referring to the explanation under Notes Receivable, it will be noted that mention was made of notes receivable discounted, the proceeds of which were debited to the Bank Account, thus raising a liability. In case a note that has been discounted is not paid at maturity, the organization will be obliged to make payment to the bank for the face value of this note, in which case the following entry will be made:

DEBIT.	CREDIT.
\$100	Notes Receivable Discounted.
	Bank Account..... \$100
	(For note of James Benton not settled for by him at maturity.)

In case the note was met at maturity, the following entry would be made:

DEBIT.	CREDIT.
\$100	Notes Receivable Discounted.
	Notes Receivable..... \$100
	(For note of James Benton settled for by him at maturity.)

In both the above cases the liability to the bank was liquidated—first, by payment of the obligation by the organization, and second, by the maker. Therefore, Notes Receivable Discounted should be debited in either case. In the first instance, however, the concern still owns the note against James Benton which is an asset for future disposal, while in the second instance the note will be canceled and returned to the maker.

When notes are discounted, the amount of the discount is to be considered as an expense and charged to an account called Interest Expense.

DEBIT.	CREDIT.
\$490	Bank Account.
10	Interest.
	Notes Receivable Discounted..... \$500
	(For notes discounted at bank with 10 per cent discount.)

COLLECTIONS ON NOTES DISCOUNTED (F 5).

DEBIT:

1. With the amount paid to the bank to liquidate Notes Receivable Discounted.

CREDIT:

1. At the end of the period with the total amount deducted from patrons' vouchers applying on Notes Receivable which have been discounted.

In organizing a new association, notes are frequently accepted in payment for subscription to capital stock, and then discounted at the bank, the proceeds being used for the purchase of necessary equipment. In payment of these notes a certain amount is deducted from the patrons' vouchers each period, and these collections should be paid to the bank to apply on patrons' notes receivable which have been discounted. In such cases the following Journal entry should be made:

DEBIT.

\$100 Collections on Notes Discounted.

CREDIT.

Bank Account..... \$100

(For payment to Bank of collections received to date on patrons' notes discounted.)

It will be evident that when the total of the payments to the bank for patrons' notes previously discounted equals the total of the face value of such notes, this liability will have been liquidated and the canceled notes should be returned to the organization or to the various makers. At this time an entry should be made debiting Notes Receivable Discounted and crediting Notes Receivable.

Such creameries deduct a certain fixed amount per pound on products delivered by the patrons during the period, the amount so deducted being applied on the payment of the notes. It is preferable to make this deduction in even dollars—\$1, \$3, etc.

ACCOUNTS PAYABLE HAULERS (F 6).

DEBIT:

1. With the amount paid haulers.

CREDIT:

1. With the amount due haulers as shown by the Balance Sheet at the time of opening the books.
2. With the amount due haulers for services during the period.
(This amount is deducted from the patrons' vouchers.)

In some creameries the patrons employ haulers to deliver their product, the creamery paying the hauler, and later this payment is deducted on the patrons' vouchers. Such disbursements do not constitute an operating expense to the organization. When the creamery makes no charge to the patrons the hauling becomes an operating expense and should be handled as any other expense account. (See p. 26.)

G. ACCRUED LIABILITIES.

INTEREST ACCRUED (G 1).

DEBIT:	CREDIT:
1. With the interest accrued on notes receivable during the period.	1. With the interest received on notes receivable.
2. With the interest paid on notes payable.	2. With the interest accrued on notes payable during the period.

The above method is believed to be advisable for smaller concerns, however. When the amount of interest accrued on either notes receivable or notes payable is considerable, it is suggested that separate accounts be opened for each of the above items, showing Interest Accrued and Notes Receivable as an asset, and Interest on Notes Payable as a liability. (See also discussion under Interest, p. 30.)

PAYROLL (G 2).

DEBIT:	CREDIT:
1. With all amounts paid to employees for services, including advances.	1. With the amount of unpaid labor as shown by the Balance Sheet at the time of opening the books.
	2. With the amount of the pay roll, including all advances, at the close of the period, as shown by the time sheet.

It is necessary to include all employees on the pay roll regardless of the department in which they are employed. The following Journal entry, which should be made at the end of each period, will illustrate the operation of this account. Example: The entire pay roll is \$400 and \$20 has been advanced during the period.

JOURNAL ENTRIES.	
DEBIT.	CREDIT.
\$135 Factory Labor.	
265 Office Labor.	
	Payroll..... \$400
	(For periodical pay roll.)
380 Payroll.	
	Bank Account..... 380
	(For payment of periodical pay roll.)

Inasmuch as the \$20 was charged to the Payroll account at the time the advance was made, the credit of \$380 to the Bank Account will close the Payroll account.

Occasionally an employee may desire an advance on his labor account, in which case the Payroll account should be debited for the amount advanced. It is not considered advisable to carry Ledger accounts with employees because of cash advances, but very careful note should be made of such advances to prevent duplicating the payment.

Should an employee purchase merchandise, the sale should be charged to his personal account. At the end of the period, or whenever the pay roll is made up, a check should be drawn in favor of the employee for the full amount of his wages. The employee should then settle his account in the regular way. By following this procedure the records will reflect clearly the transactions involved.

The following Journal entry will illustrate this procedure:

DEBIT.		CREDIT.
\$8.50	John Jones.	
	Merchandise Sales.....	\$8.50
	(For sale of merchandise to John Jones, employee.)	

John Jones would then receive his entire wages and would settle for his account by the following transactions:

DEBIT.		CREDIT.
\$8.50	Cash.	
	John Jones.....	\$3.50
	(For payment of John Jones' account.)	
	TAXES ACCRUED (G 3).	

DEBIT:	CREDIT:
1. With the amount actually paid for taxes.	1. With the amount of accrued taxes as shown by the Balance Sheet at the time of opening the books.
	2. At the close of the period with its proportion of estimated annual taxes.

At the beginning of the fiscal year an estimate of the taxes which will become due during the succeeding 12 months should be made. The amount of this estimate, if given careful consideration, can be made to approximate very closely the taxes which are actually assessed. Normally, this amount will show a credit balance which represents the liability for taxes accrued but not due. However, when the tax payment is made during the fiscal year there will be a debit balance. This will be gradually adjusted as the periodical entries are made. Any balance on this account after the yearly taxes have been paid should be transferred at the end of the fiscal year to the Taxes account.

H. RESERVES.

RESERVE FOR DOUBTFUL ACCOUNTS (H 1).

DEBIT:	CREDIT:
1. With all accounts charged off as uncollectible.	1. With the amount reserved to cover doubtful accounts as shown by the Balance Sheet at the time of opening the books.
	2. At the close of each period with its proportion of estimated annual loss due to bad accounts.

Any collections received on an account that has been previously charged off should be credited to this account. This periodical charge should be based on the amount of annual sales and previous losses from this source.

RESERVE FOR DEPRECIATION ON MOTOR VEHICLES (H 2).

DEBIT:

1. With the book value of any item discarded or replaced by new equipment.

CREDIT:

1. With the amount of reserve as shown by the Balance Sheet at the time of opening the books.
2. At the close of the period with the proportion of annual loss resulting from wear, tear, or obsolescence.
3. With the amount received from the sale of scrapped or discarded equipment.

It is suggested that a rate of not less than 25 per cent be charged off annually.

RESERVE FOR DEPRECIATION ON PLANT (H 3).

DEBIT:

1. With the book value of any item discarded or replaced by new equipment.

CREDIT:

1. With the amount of reserve as shown by the Balance Sheet at the time of opening the books.
2. At the close of the period with the proportion of annual loss due to wear, tear, and obsolescence.
3. With the amount received from the sale of any discarded or scrapped material.

Owing to the conditions existing in some types of plants and to the peculiar nature of the work involved, the wear and tear on equipment is excessive. Special consideration should be given to these plant conditions in order that adequate reserves for depreciation may be provided.

In an organization where a more detailed segregation of accounting data is desired, this account should be replaced by a separate account showing reserves for depreciation on buildings, machinery, equipment, etc.

RESERVE FOR DIVIDENDS PAYABLE (H 4).

DEBIT:

1. At the time of payment with the total of checks paid to the stockholders as dividends.

CREDIT:

1. At the close of the period with the proportion of the annual dividend to the stockholders.
(Debit Dividend Appropriation.)

It can be readily understood that those stockholders who have loaned their money to the organization, taking certificates of stock as security thereon, are entitled to be reimbursed for the use of their money, and in many instances this reimbursement is authorized by the by-laws. However, only those stockholders whose subscriptions have been fully paid should receive any share of the dividend payment. A periodical entry should be made as follows:

DEBIT.		CREDIT.
\$50.	Dividend Appropriation.	
	Dividends Payable.....	\$50.
	(To set aside an amount to be used in paying dividends at the close of the fiscal year.)	

At the end of the fiscal year sufficient funds should have been reserved to cover the dividend. When the dividend checks are written an entry should be made debiting Dividends Payable account and crediting Bank Account. In case this entry does not close the Dividends Payable account, it should be closed by a debit or credit, as the case may be, to Surplus Adjustment.

The Dividends Payable account will be carried only by cooperative creameries. It should be constantly borne in mind that the dividends thus provided are not deductible as an expense item in computing the income tax.

SINKING FUND RESERVE.

In the by-laws of a large number of creameries there is found a provision for the creation of what is called a sinking fund. This so-called sinking fund is created by withholding from the income distributable to patrons a certain amount per pound of butter fat received. This fund is to be used to pay the expenses of the creamery.

Referring to the definition of a sinking fund given on page 9 it is at once evident that the mere withholding from patrons of a certain amount per pound of butter fat received will not establish a sinking fund, or anything which in any way resembles such a fund, inasmuch as the amount provided by the by-laws has not been "withdrawn from the general funds of the business," nor has it been "invested in securities or deposited in a savings account." In reality the only thing which has been accomplished is the placing of a limit on the operating expenses and the creating of a reserve against which certain expenses are chargeable. Under this method part of the expenses are charged into the Loss and Gain account at the end of the year, and another part (those charged to Sinking Fund Reserve) are not. It is then impossible to determine from the books the cost of operating the business without considerable additional work and only an expert bookkeeper is able to prepare a statement which will show the true cost.

Too little consideration is given to the fact that on account of the variation in the total operating expense from month to month, deductions for expense based on an estimate must necessarily be either more or less than the actual expense. Either will affect the returns from future operations; a deficit will require that deductions be made from income in addition to those necessary for current expenses, and a surplus will make necessary the distribution of the previous year's earnings thus accumulated. For this reason it has been found that the creation of a reserve to meet expenses is extremely undesirable, and it is recommended that the by-laws of creameries operating under this plan be amended, and that such a plan be omitted in the organization of new creameries. This method of controlling expenses serves no useful purpose and the greatest benefits to all concerned would result if it could be replaced by a more modern and efficient one.

However, numerous creameries will probably retain this clause in their by-laws, and therefore the accounting procedure necessary in such cases will be discussed here. When the by-laws contain the provisions just referred to, the term Operating Reserve should be used to indicate the account to which will be credited all income withheld from distributions to patrons for this purpose of meeting expenses. The terms Sinking Fund Reserve (see p. 20) and Sinking Fund must not be used in this connection.

OPERATING RESERVE.

DEBIT:

1. With all expenditures which this reserve is created to meet.

CREDIT:

1. With amounts withheld from distribution to patrons for the purpose of meeting expenses.

Unusual losses, new equipment, and other items are frequently included in this account, as well as the expense items for which the account was created. This should never be done. The amounts set aside to defray expenses are charged into the Loss and Gain account against gross income, and will ordinarily be allowable as a deduction in preparing income tax returns, whereas amounts set aside to provide for unusual items are not allowed as a deduction in preparing such returns, and are not chargeable in the Loss and Gain account against gross income.

Should it be desirable to set up a reserve to meet a contingency which may arise in the future, a special account should be opened for this purpose.

SINKING FUND RESERVE (H 5).

DEBIT:	CREDIT:
1. With the amount of the sinking fund when the obligations for which it was created have been paid. (Credit Surplus.)	1. With the amount to be set aside periodically to provide for the payment of a fixed obligation at some future time. (Debit Sinking Fund Appropriation.)

It should be noted, also, that a Sinking Fund Reserve can be created out of profits, whether or not a sinking fund as described on page 9 has been created.

I. NET WORTH.

CAPITAL STOCK (I 1).

DEBIT:	CREDIT:
1. With the par value of shares retired or canceled.	1. With the par value of all shares issued as shown by the Balance Sheet at the time of opening the books. 2. With the par value of all shares sold subsequently.

The capital stock of a corporation is divided into shares, each share usually having a designated par value. These shares may be transferred from one individual to another without affecting the capital of the corporation. The ownership of a share of capital stock is evidenced by a stock certificate.

In organizing a corporation, a subscription list should first be prepared, the signers of which bind themselves by law to purchase the number of shares subscribed. No certificate of stock should be delivered to a stockholder until his subscription has been fully paid. Until such payment is made, a temporary certificate may be given to the subscriber to be exchanged for the regular stock certificate on completion of payment.

When a subscription list has been prepared and the corporation formed on this basis, it is often provided that the subscription may be paid in installments. To credit these partial payments direct to the capital stock account is undesirable. In view of this, when the subscription list has been completed an entry should be made debiting Subscription account and crediting Capital Stock account for the amount subscribed. When payments of the subscription are made, either by cash or note, in full or in part, these payments should be credited to Subscription account and not to Capital Stock account. The following entries will illustrate:

DEBIT.		CREDIT.
\$10,000	Subscription account.	
	Capital stock.....	\$10,000
For subscription shown on subscription list No. 1.		
DEBIT.		CREDIT.
\$4,000	Cash.	
1,000	Notes Receivable.	
	Subscription account.....	\$5,000
	50 per cent payment of the following subscriptions:	
	(List of those making payment.)	

In case the entire capital stock is paid at one time, the following method might be used.

Entries to illustrate issue of capital stock and payment thereof:

DEBIT.		CREDIT.
\$8,000	Cash.	
2,000	Notes Receivable.	
	Capital Stock.....	\$10,000
	(Representing payment of capital stock issued to the following:)	

When shares of stock are acquired or sold for more or less than par value, the premium or discount should be charged or credited as the case may be to Premium and Discount on Capital Stock account. For example, if a going concern desires to sell additional shares, the shares being above par in value, an entry should be made as follows:

DEBIT.		CREDIT.
\$105	Cash.	
	Capital Stock.....	\$100
	Premium and Discount on Capital Stock.....	5
	(For sale of one share of stock at \$5 premium.)	

Likewise, if shares were sold at a discount, there would be a debit to Premium and Discount on Capital Stock.

The balance in this account should be written off into the Surplus account by periodical charges usually extending over a term of years.

It occasionally happens that capital stock is offered for sale, and is purchased by the organization, to be held for resale at some future date. While this transaction may seem to resemble closely a retirement of the capital stock so purchased, and as such chargeable to the Capital Stock account, accountants generally have preferred to charge a purchase made in this manner to an account called Treasury Stock. In case the purchase was made above par, the entry should be:

DEBIT.		CREDIT.
\$105	Treasury Stock.	
	Cash.....	\$105
	(For purchase of one share of stock from Chas. Brown at \$5 premium.)	

When Treasury Stock is sold, the total amount received from such sale should be credited to the Treasury Stock account. Although it is not incorrect to charge the par value of this purchase to Capital Stock, it is a procedure not to be recommended.

In case the organization is not a corporation, but a partnership, sole ownership, or association, the Capital Stock account would be replaced by accounts indicating the ownership, membership, or amount of certificate of indebtedness outstanding.

SURPLUS (I 2.)

DEBIT:

1. With any debit balance of the Loss and Gain account at the close of the fiscal year.

CREDIT:

1. With the amount of surplus as shown by the Balance Sheet at the time of opening the books.
2. With the net profit as shown by the credit balance of the Loss and Gain account at the close of the fiscal year.

Any balance from the Surplus Adjustment account should be carried to the Surplus account at the end of the fiscal year, either as a debit or credit. In many organizations the Surplus account represents the excess of assets over liabilities and capital stock. However, when a certain amount, commonly called a Reserve for Sinking Fund (see p. 19), is set aside out of earnings each year to retire the capital stock at a definite time, this reserve, together with the Capital Stock and Surplus, equals the excess of assets.

When the opening Balance Sheet shows the liabilities, capital stock, and accumulated reserves to be in excess of the total assets including good will, the Surplus account will show a debit balance. When this is the case there has evidently been a loss through operation which in reality amounts to an impairment of capital. The amount of such debit balance should be debited to an account captioned Deficit. At the close of each following fiscal year, the Loss and Gain account and the Surplus Adjustment account should be closed into this account until the deficit is written off.

The Deficit account is in reality the debit side of the Surplus account, but should be carried under a different caption. For example, if there is no surplus and a Loss is sustained during the year, the loss shown by the debit balance of the Loss and Gain account is an impairment of the capital and should be carried to the Deficit account by the following Journal entry:

DEBIT.		CREDIT.
\$1,500	Deficit.	
	Loss and Gain.....	\$1,500
	(To close Loss and Gain into Deficit account.)	

If the company makes a net profit of \$2,000 during the succeeding year, the Journal entry will be as follows:

DEBIT.		CREDIT.
\$2,000	Loss and Gain.	
	Deficit.....	\$1,500
	Surplus.....	1,500
	(To close the Deficit and Loss and Gain account.)	

LOSS AND GAIN (I 3).

DEBIT:

1. With the balance of any account charged with purchases of raw material for manufacture.
2. At the close of the fiscal year or other accounting period with the debit balance of all Expense accounts.

CREDIT:

1. With the balances of all Income accounts.

During the year it is frequently found that errors or omissions were made in the work of closing the books for the previous year. These corrections should not be made through the Loss and Gain account but by making the adjustments direct to the Surplus account or to a Surplus Adjustment account. Any unusual item of profit or loss, such as might arise from a sale of land, buildings, etc., must not be entered in the Loss and Gain account, but must be entered in the Surplus account.

By referring to the illustration on page 35, it will be seen that the result of the Income and Expense Statement is the showing of Net Profit. This is the balance of the Loss and Gain account. It is now desirable to show what disposition is made of the net income, and this is effected by the last section of the statement, captioned Distribution of Net Profit. This is sometimes accomplished by the use of another account called Undivided Profits. However, it seems that the same results may be accomplished by the method here shown, without opening the additional account in the Ledger.

INCOME ACCOUNTS.

J. SALES.

BUTTER SALES (J 1).

DEBIT:

1. With the sale value of any butter that may be returned by a customer.
2. With the balance at the close of the fiscal year. (Credit Loss and Gain.)

CREDIT:

1. At the close of each period with the total sales during the period.

CREAM SALES (J 2).

DEBIT:

1. With the sale value of any cream that may be returned by a customer.
2. With the balance at the close of the fiscal year. (Credit Loss and Gain.)

CREDIT:

1. At the close of the period with the total sales during the period.

MILK SALES (J 3).

DEBIT:

1. With the sale value of any milk that may be returned by a customer.
2. With the balance at the close of the fiscal year. (Credit Loss and Gain.)

CREDIT:

1. At the close of the period, with the total sales during the period.

CHEESE SALES (J 4).

DEBIT:

1. With the sale value of any cheese that may be returned by a customer.
2. With the balance at the close of the fiscal year. (Credit Loss and Gain.)

CREDIT:

1. At the close of the period, with the total sales during the period.

BUTTERMILK SALES (J 5).

DEBIT: 1. With the sale value of any buttermilk that may be returned by a customer. 2. With the balance at the close of the fiscal year. (Credit Loss and Gain.)	CREDIT: 1. At the close of the period, with the total sales during the period.
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K. MISCELLANEOUS INCOME.

MERCHANDISE SALES (K 1).

DEBIT: 1. With the sale value of any merchandise that may be returned by a customer. 2. With the balance at the close of fiscal year. (Credit Loss and Gain.)	CREDIT: 1. At the close of the period, with the total sales during the period.
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This account is to take care of sales of miscellaneous merchandise, such as eggs, grain, etc.

The credit balances of all Sales accounts should be credited to Loss and Gain at the close of the fiscal year, thus closing the Sales accounts.

Any sales to patrons of supplies, packages and liners, salt, ice, or other merchandise, which are used in the manufacture, packing, or shipping of products should be credited to the Inventory accounts affected, and debited to Patrons' Accounts Receivable.

DISCOUNT RECEIVED (K 2).

DEBIT: 1. With the credit balance at the close of the fiscal year. (Credit Loss and Gain.)	CREDIT: 1. With any income arising from cash discounts deducted from invoices paid.
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EXPENSE ACCOUNTS.

L. RAW MATERIAL.

BUTTER FAT PURCHASES (L 1).

DEBIT: 1. With the amount to be paid to the patrons for butter fat delivered during the period.	CREDIT: 1. With the amount of undistributed balance. 2. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.)
---	---

There are two distinct methods of settling with patrons for deliveries of butter fat. The first method is to pay according to the market quotations regardless of operating expense; the second is to pay the patrons the entire net income, that is, the total receipts from product, less the total expense. The second method is to be followed in nearly all cooperative creameries.

In creameries following the first procedure, the periodical debit to butter-fat purchases will be the total of deductions for butter delivered to patrons for hauling, for supplies sold to patrons, for collections on notes, etc., as well as payments in cash or by check, as shown by the recapitulation of patrons' vouchers on the Patrons' Settlement Sheet.

Suppose that the Patrons' Settlement Sheet at the close of the period shows:

Amount to be paid by check.....	\$9,500
Butter sales to patrons.....	450
Supplies sold to patrons.....	40

The entry would be:

DEBIT.	CREDIT.
\$9,900. Butter Fat Purchases.	
Patrons' Accounts Receivable—Butter Sold.....	\$490
Accounts Payable Patrons.....	9,500

The procedure under the second method is fully described on page 20, U. S. Department of Agriculture Bulletin 559, "Accounting Records for Country Creameries." However, it has been found desirable to substitute for the account Patrons' Overdrafts, the account Patrons' Accounts Receivable, operation of which is described on page 7 of this bulletin.

In some creameries any balance undistributed is allowed to accumulate and is distributed at a later date in the form of a patronage dividend. When this is done, the undistributed balance should be credited to an account captioned Patronage Dividend account and should not be carried forward to the next Operating Statement.

A patronage dividend is in reality a deferred payment and is advised against, as it necessitates considerable clerical labor, with no apparent advantage. The Patronage Dividend account would be closed by debit, and the corresponding credit to the Bank account.

The Undistributed Balance account is not raised in the Ledger, inasmuch as it is immediately closed by a debit, the corresponding credit being carried to Butter Fat Purchases.

However, in preparing a Balance Sheet, such undistributed balance should be shown as a part of the liabilities as illustrated on page 34.

SKIM MILK PURCHASES (L 2).

DEBIT:	CREDIT:
1. With the amount due patrons for skim milk purchased during the period.	1. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.)

UNDERPAYMENTS AND OVERPAYMENTS (L 3).

DEBIT:	CREDIT:
1. With the amount paid to patrons on account of errors in vouchers.	1. With the amount received from patrons on account of errors in vouchers.

This account would be used only by creameries operating on the cooperative plan; when it would be shown on the Operating Statement as all other expenses.

Should it happen that an error is made in figuring a patron's voucher, any balance due him should be immediately paid upon verification as to the accuracy of the claim and the amount carried to the debit of this account.

In case an overpayment has been made to a patron, he should be induced, if possible, to reimburse the company immediately. Otherwise the amount will appear as a deduction on his next voucher, which is undesirable. Such refunds will be a credit to this account.

The balance of this account should be carried to Butter Fat Purchases' account, either as a debit or credit, as the case may be, before the Loss and Gain account is written up.

AUTOMOBILE TRUCK OPERATION (L 4).

DEBIT:	CREDIT:
1. With all expenses incurred for oil, gasoline, rent, driver's wages, license fees, and cleaning.	1. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.)

If the situation warrants, a separate labor account under Collection and Delivery Expenses may be maintained, but in most cases this would be an unnecessary segregation. The Automobile Truck Operation expense account should show the expense of actual operation, exclusive of repairs.

REPAIRS ON AUTOMOBILE TRUCK (L 5).

DEBIT:	CREDIT:
1. With the cost of all items of repairs on automobile trucks during the period.	1. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.)

Considerable care must be exercised in determining what should be charged to this account. These charges should include repairs of all sorts, but should not include charges for replacement of entire unit. Additional equipment to a truck increasing its valuation should be charged to Automobile Truck Inventory account.

DEPRECIATION ON AUTOMOBILE TRUCKS (L 6).

DEBIT:	CREDIT:
1. At the close of the period, with proportion of annual reserve set aside to cover the estimated wear and tear on automobile truck.	1. With the debit balance at close of the fiscal year. (Debit Loss and Gain.)

HAULING EXPENSE.

In some organizations this expense, or a part of it, is paid by the patrons. When the entire cost is so paid, the proper method of bookkeeping is described under Accounts Payable Haulers on page 15. However, when any part of this cost is paid by the creamery, an account captioned Hauling Expense should be opened under the Raw Material account. All amounts paid to haulers would be charged to this account, and all charges to producers would be credited to this account. The debit balance would represent the expense to the creamery of collecting the raw material.

M. OPERATING EXPENSE.

LABOR (M 1).

DEBIT:

1. With the amount actually earned for the period by all factory employees as shown by the time sheet. (Credit Payroll account.)

CREDIT:

1. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.)

It will be noticed that this account is not charged with *advances* to employees nor with the amount *paid* to employees, but with the amount actually *earned* during the period. All payments, of whatever nature, are charged to Payroll account. (See p. 16.)

POWER AND REFRIGERATION (M 2).

DEBIT:

1. With the cost of all material of any nature used as fuel in producing power.
2. With the cost of electricity used for light and power.
3. With the cost of water.
4. With cost of all materials used in refrigerating machines or ice boxes (such as ammonia, calcium, ice, etc.).

CREDIT:

1. With the debit balance at the end of the fiscal period. (Debit Loss and Gain.)

In those organizations which desire detailed information relative to the cost of power and refrigeration, this account should be replaced by others which will give the desired detail.

MANUFACTURING SUPPLIES (M 3).

DEBIT:

1. With the cost of all materials used in the process of manufacturing, such as packages and liners, salt, butter color, starter, etc.

CREDIT:

1. With debit balance at the end of the fiscal period. (Debit Loss and Gain.)

REPAIRS ON PLANT (M 4).

DEBIT:

1. With the total amount expended for repairs to buildings, machinery, and equipment, as shown by invoice or other vouchers.

CREDIT:

1. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.)

Considerable care must be exercised in determining what should be charged to this account. These charges should include repairs of all sorts but should not include charges for replacement of entire units. The various invoices covering such expenditures should be carefully analyzed and treated individually.

Another method of taking care of these expenses for repairs to machinery and equipment, as well as to buildings, is to set up a Reserve for Depreciation on both these assets sufficient to cover all such expenses. This latter method is being recommended by some accountants.

DEPRECIATION ON PLANT (M 5).

DEBIT:	CREDIT:
1. At the close of the period with the proportion of the annual reserve set aside to cover the estimated wear, tear, and obsolescence on buildings and machinery and equipment.	1. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.)

The periodical proportion of the wear and tear on the plant is an expense and should be very carefully estimated. The question of the proper rate to apply as a charge for depreciation for an entire plant is one that can hardly be covered by a general statement, as local conditions are rarely comparable. In some instances a machine may last five years; in others it may last hardly a year, depending upon its load and care. The rate of depreciation will vary from 3 per cent in some cases to 20 per cent, depending upon the kind of building and machinery in use.

TOOL REPLACEMENT (M 6).

DEBIT:	CREDIT:
1. With the total amount expended for small tools during the period.	1. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.)

Inasmuch as the investment in small tools will remain substantially the same at all times, it is suggested that in order to avoid taking an inventory and setting up a Reserve for Depreciation on Tools, all purchases be carried direct to Tool Replacement expense. This method is believed to be much more simple and satisfactory than that of maintaining a depreciation account as in the case of machinery and equipment.

N. ADMINISTRATION AND SELLING.

EXPRESS, FREIGHT, AND DRAYAGE (N 1).

DEBIT:	CREDIT:
1. With any cost of freight, express, and drayage on inbound goods when such an expense can not be allocated to a particular inventory account.	1. With the debit balance at close of the fiscal year. (Debit Loss and Gain.)
2. With any cost of freight, express, and drayage on product shipped.	

All other charges for freight, express, or drayage should be charged direct to the inventory account for the article purchased.

TELEPHONE, TELEGRAPH, AND POSTAGE (N 2).

DEBIT:

1. With the total amount expended during the period for items of postage, telegraph, telephone, and messenger fees.

CREDIT:

1. With the debit balance at close of the fiscal year. (Debit Loss and Gain.)

OFFICE SALARIES (N 3).

DEBIT:

1. With any amount actually earned by office employees applying to the period covered by the pay roll. (Credit Payroll account.)

CREDIT:

1. With the debit balance at close of the fiscal year. (Debit Loss and Gain.)

For further discussion on handling this account, see Labor Expense and the comments under Payroll.

OFFICE SUPPLIES (N 4).

DEBIT:

1. At the close of the period with the estimated amount of printing, stationery, and supplies consumed. (Credit Printing and Stationery Inventory.)
2. With the cost of current purchases of small supplies.

CREDIT:

1. With the debit balance at close of the fiscal year. (Debit Loss and Gain.)

As it is impracticable to determine the exact amount consumed periodically, a liberal estimate of the consumption, rather than an attempt at actual inventory, should be charged to this account.

TAXES (N 5).

DEBIT:

1. At the close of the period with the proportion of the annual tax chargeable to the period. (Credit Taxes Accrued.)

CREDIT:

1. With the debit balance at close of the fiscal year. (Debit Loss and Gain.)

INSURANCE (N 6).

DEBIT:

1. At the close of the period with the proportion of the annual amount chargeable to the period. (Credit Prepaid Insurance.)

CREDIT:

1. With the debit balance at close of the fiscal year. (Debit Loss and Gain.)

INTEREST (N7).

DEBIT:	CREDIT:
1. At the close of the period with the interest accrued during the period on Notes Payable. (Credit Interest Accrued.)	1. At the close of the period with the interest accrued during the period on notes receivable.
2. With the discount charged on notes receivable discounted.	

The debits or credits offsetting the entries of interest accrued will be made to the Interest Accrued account. At the close of the fiscal year the debits of this account should be transferred to the debit of the Loss and Gain account, and the credits should be transferred to the credit of Loss and Gain account.

The above method is advisable for small concerns. However, in case both interest paid and interest earned be considerable, it is suggested that separate accounts be opened for Interest Expense and Interest Earned.

LOSS FROM BAD ACCOUNTS (N8).

DEBIT:	CREDIT:
1. At the close of the period with the proportion of the estimated annual loss through bad accounts. (Credit Reserve for Doubtful Accounts.)	1. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.)

MISCELLANEOUS EXPENSE (N9).

DEBIT:	CREDIT:
1. With the cost of any items of expense not chargeable to any of the foregoing accounts.	1. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.)

To this account should be charged donations to charitable organizations and any other expense that can not be charged to any of the other accounts.

O. PURCHASES.

MERCHANDISE PURCHASES (O1).

DEBIT:	CREDIT:
1. With the cost of all merchandise purchased for direct sale during the period.	1. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.)

P. APPROPRIATION ACCOUNTS.**DIVIDEND APPROPRIATION (P1).****DEBIT:**

1. At the close of the period with the proportion of annual dividend chargeable to the period. (Credit Reserve for Dividends Payable.)

CREDIT:

1. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.)²

For further discussion, see Reserve for Dividends Payable, page 18.

SINKING FUND APPROPRIATION (P2).**DEBIT:**

1. With the amounts deducted from gross income as authorized by the by-laws or by order of the Board of Directors. (Credit Sinking Fund Reserve.)

CREDIT:

1. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.)²

For further discussion, see Sinking Fund Reserve, page 19.

TRIAL BALANCE.

While the Trial Balance is not a financial statement, it serves to prove the postings of the entries to the Ledger from the books of original entry. It is a summary of the various balances as they appear in the Ledger and should be drawn off before closing the Expense and Income accounts into the Loss and Gain account. If no mistake has been made in posting to the Ledger, the total of the debits will equal a total of the credits. A trial balance should always be taken at the end of every period and all errors should be located and corrected at once.

CLOSING THE BOOKS.

Preparatory to closing the books, an inventory should be taken of all supplies on hand and should be written up in permanent form. With it should be included a schedule of expense items, such as postage, stationery, and supplies on hand, and of the unconsumed balances of such accounts as Prepaid Insurance and Prepaid Taxes.

The balances of all Expense, Income, and Purchase accounts should be transferred to the Loss and Gain account in order to ascertain the net income or loss for the season's operation. The accounts should then be ruled, and the balance brought down. This balance is the net income for the year. Against this net income should then be charged the balances of the Dividend Appropriation and Sinking Fund Appropriation accounts. The balance of the Loss and Gain account should then be transferred to the Surplus account.

After the books are closed and a post-closing Trial Balance has been taken to prove the mechanical accuracy of the work, the various financial statements are made up for presentation to the Board of Directors.

² Care should be exercised that this balance be transferred to Loss and Gain only after the net income has been determined, as shown by the form illustrated on page 35 and 36.

The following Journal entries will illustrate the procedure necessary to close the books:

ENTRY No. 1.		
DEBIT.		CREDIT.
000 Butter Sales.		
000 Cream Sales.		
000 Milk Sales.		
000 Cheese Sales.		
000 Buttermilk Sales.		
000 Merchandise Sales.		
	Loss and Gain.....	000
	(To close the Sales accounts into Loss and Gain.)	

ENTRY No. 2.		
000 Discount Received.		
	Loss and Gain.....	000
	(To close the Discount Received account into Loss and Gain.)	

ENTRY No. 3.		
000 Loss and Gain.		
	Butter Fat Purchases.....	000
	Skim Milk Purchases.....	000
	Merchandise Purchases.....	000
	(To close the Purchase accounts into Loss and Gain.)	

ENTRY No. 4.		
000 Loss and Gain.		
	Labor.....	000
	Power and Refrigeration.....	000
	Manufacturing Supplies.....	000
	Repairs on Plant.....	000
	Tool Replacement.....	000
	Depreciation on Plant.....	000
	Automobile Truck Operation.....	000
	Repairs on Automobile Truck.....	000
	Depreciation on Automobile Truck.....	000
	Express, Freight, and Drayage.....	000
	Telephone, Telegraph, and Postage.....	000
	Office Salaries.....	000
	Office Supplies.....	000
	Underpayments and Overpayments.....	000
	Taxes.....	000
	Insurance.....	000
	Interest.....	000
	Loss from Bad Accounts.....	000
	Miscellaneous.....	000
	(To close the Expense accounts into Loss and Gain.)	

At this point the Loss and Gain account should be ruled and the balance brought down as net income or net loss. The following entry should then be made:

DEBIT.		CREDIT.
000 Loss and Gain.		
	Dividend Appropriation.....	000
	Sinking Fund Appropriation.....	000
	(To close the Appropriation accounts into Loss and Gain.)	

The balance of the Loss and Gain account should then be transferred to the Surplus account upon direction of the Board of Directors.

BALANCE SHEET.

After closing the Expense and Income accounts into Loss and Gain there will remain in the Ledger the Asset, Liability, Reserve, and Net Worth accounts, which are the Balance Sheet accounts. As has previously been stated, the Assets accounts should be arranged on the left-hand side of the Balance Sheet in the order of their probable cash realization and the Liabilities and Net Worth accounts arranged on the right-hand side in the order of their probable priority as to liquidation. The purpose of the Balance Sheet is to present the assets and liabilities of the organization in concrete form and reveal the net worth as at a certain time. It is one of the most important statements to be prepared and should show by comparison with former similar statements, the financial progress of the organization.

The following form of a Balance Sheet is recommended as a model to be used in preparing these statements. Attention is invited to the fact that while the Ledger shows the various reserves for depreciation as a credit balance, they are shown on the Balance Sheet as a deduction from assets, and also that while good will may be considered as an intangible asset, it is shown on the credit side of the Balance Sheet as a deduction from the Net Worth accounts. This procedure is in conformity with the recommendation of the Federal Reserve Board.

Balance Sheet as at December 31, 19—.
BLANK CREAMERY COMPANY.

Account No.	Assets.	Current year.		Last year.	Account No.	Liabilities.	Current year.		Last year.
A 1.....	Current Assets:				F 1.....	Current Liabilities:			
A 2.....	Cash—				F 2.....	Notes Payable.....			
A 3.....	On Hand.....				F 3.....	Accounts Payable.....			
	In Bank.....				F 4.....	Undistributed Balance ¹			
	Notes Receivable.....				F 5.....	Notes Receivable Discounted.....			
	Interest Accrued on Notes Receivable.....					Collections on Notes Discounted.....			
A 4.....	Accounts Receivable.....				G 1.....	Accrued Liabilities—			
H 1.....	Less Reserve for Doubtful Accounts.....				G 2.....	Interest Accrued on Notes Payable.....			
A 5.....	Patrons' Account Receivable.....				G 3.....	Payroll.....			
A 6.....	Inventories—					Taxes Accrued.....			
	Manufactured Product:					Total Current Liabilities.....			
	Butter.....				H 6.....	Reserves:			
A 7.....	Operating Supplies.....				H 7.....	Dividends Payable.....			
						Sinking Fund.....			
B 1.....	Total Current Assets.....					Total Reserves.....			
C 1.....	Sinking Fund.....								
C 2.....	Fixed Assets:								
	Land.....								
C 3.....	Buildings.....								
	Machinery and Equipment.....								
H 3.....	Less Reserve for Depreciation on Plant.....								
C 4.....	Tools.....								
C 5.....	Motor Vehicles.....								
H 2.....	Less Reserve for Depreciation.....								
C 6.....	Office Furniture and Equipment.....								
	Total Fixed Assets.....				I 1.....	Net Worth:			
D 1.....	Prepaid Expense:					Capital Stock Authorized.....			
	Prepaid Insurance.....					Less Unsubscribed.....			
D 2.....	Printing and Stationery.....				I 2.....	Surplus and Undivided Profits.....			
						Less Deficit.....			
	Total Prepaid Expense.....					Total Net Worth.....			
	Totals.....					Totals.....			

¹ To be distributed to patrons the following month.

INCOME AND EXPENSE STATEMENT.

The Income and Expense Statement is an itemized statement of the entries made to the Loss and Gain account, arranged in such a way as to set forth clearly the results of the operations of the periods involved.

The following form of Income and Expense Statement will be found convenient for exhibiting the operations of the creamery for either a monthly or a yearly period. Whenever possible a monthly statement of income and expense is advised. In the past no standard form of Income and Expense Statement has been used; therefore, this form should fill a very definite need. By its use not only the stockholders and directors may follow the details of the business, but a ready comparison may be made between the costs of operation of various periods.

The amounts shown as sales and purchases in this statement should be net figures. That is, merchandise returned by the buyer should be deducted from the total sales, and merchandise returned by the company to the concern from whom it was purchased should be deducted from the total purchases.

In preparing the trading section of the Income and Expense Statement, it will be found that a space is provided for showing the inventory at the beginning of the period separately from the purchases. If the entries have been made in the order provided, the amount of the inventory existing at the close of the previous period should be the first item in the various Purchase accounts. By deducting this amount from the balance on the Purchase accounts the purchases for the period may be found.

THE BLANK CREAMERY COMPANY, BLANK, VERMONT.

Income and Expense Statement for , 19—

Account No.		Current year.			Last year.		
J 1	Butter Sales.....	.....	.....	.....	.....	.....	.....
J 2	Cream Sales.....	.....	.....	.....	.....	.....	.....
J 3	Milk Sales.....	.....	.....	.....	.....	.....	.....
J 4	Cheese Sales.....	.....	.....	.....	.....	.....	.....
J 5	Buttermilk Sales.....	.....	.....	.....	.....	.....	.....
	Total Sales.....	.....	.....	.....	.....	.....	.....
	Less Returned Sales.....	.....	.....	.....	.....	.....	.....
	Net Sales.....	.....	.....	.....	.....	.....	.....
	Raw Material:						
L 1	Butter Fat Purchases.....	.....	.....	.....	.....	.....	.....
L 2	Skim Milk Purchases.....	.....	.....	.....	.....	.....	.....
L 3	Underpayments and Overpayments.....	.....	.....	.....	.....	.....	.....
	Collection Expense:						
L 4	Auto Truck Operation.....	.....	.....	.....	.....	.....	.....
L 5	Repairs on Auto Trucks.....	.....	.....	.....	.....	.....	.....
L 6	Depreciation on Auto Trucks.....	.....	.....	.....	.....	.....	.....
	Total Cost of Raw Material.....	.....	.....	.....	.....	.....	.....
	Operating Expense:						
M 1	Labor.....	.....	.....	.....	.....	.....	.....
M 2	Power and Refrigeration.....	.....	.....	.....	.....	.....	.....
M 3	Manufacturing Supplies.....	.....	.....	.....	.....	.....	.....
M 4	Repairs on Plant.....	.....	.....	.....	.....	.....	.....
M 5	Depreciation on Plant.....	.....	.....	.....	.....	.....	.....
M 6	Tool Replacement.....	.....	.....	.....	.....	.....	.....
	Total Operating Expense.....	.....	.....	.....	.....	.....	.....
	Add:						
	Inventory beginning of year.....	.....	.....	.....	.....	.....	.....
	Deduct:						
	Inventory end of year.....	.....	.....	.....	.....	.....	.....
	Manufacturing Cost of Goods Sold.....	.....	.....	.....	.....	.....	.....
	Gross Profit.....	.....	.....	.....	.....	.....	.....

Income and Expense Statement for 19—Continued.

Account No.		Current year.			Last year.		
	Gross Profit forward.....						
	Administration and Selling:						
N 1	Express, Freight, and Drayage.....						
N 2	Telephone, Telegraph, and Postage.....						
N 3	Office Salaries.....						
N 4	Office Supplies.....						
N 5	Taxes.....						
N 6	Insurance.....						
N 7	Interest.....						
N 8	Loss from Bad Accounts.....						
N 9	Miscellaneous Expense.....						
	Total Administration Expense.....						
	Operating Profit.....						
K 1	Miscellaneous Income:						
O 1	Merchandise Sales.....						
	Merchandise Purchases.....						
	Inventory beginning of year.....						
	Less Inventory end of year.....						
	Cost of Merchandise Sales.....						
	Merchandise Profit.....						
	Discount Received.....						
	Net Miscellaneous Income.....						
	Net Profit.....						
	Distribution of Net Profit:						
P 1	Dividend Appropriation.....						
P 2	Sinking Fund Appropriation.....						
I 2	Surplus.....						
	Total.....						

INSTALLATION OF ADDITIONAL EQUIPMENT.

It may be well to discuss the procedure to be followed in case additional equipment is installed or new buildings are constructed to accommodate the expansion of the business. This expense may possibly be met by selling more capital stock. However, if the authorized capital stock has been entirely sold, this procedure would first necessitate receiving approval of the proper State officials to increase the capitalization. This method of securing additional funds is often impracticable, however, and the amount may be raised by placing a sufficient mortgage on the plant to meet the cost of the proposed expansion. In case the plant is mortgaged, an amount sufficient to liquidate the indebtedness at maturity will necessarily have to be deducted periodically from the gross earnings. This is the proper scope of the sinking fund as referred to in the first paragraph in this discussion. The interest on the mortgage should be paid annually and included in the Operating Expense. This amount deducted should be regularly deposited in a savings account, and there should in no case ever be a possibility of using this fund to pay current expenses.

However, if neither of the above methods can be adopted, it will then become necessary to anticipate the expansion and withhold periodically a certain amount from the earnings. The amount thus withheld should be deposited in a savings account and not merged with the ordinary bank account. The following entries will illustrate the procedure to raise the reserve and other accounts. Assume that \$5,000 is the necessary amount to be raised for the purpose of installing a new refrigerating plant.

DEBIT.		CREDIT.
\$1,000	Additional Equipment Appropriation (Refrigerating Plant).	
	Reserve for Additional Equipment.....	\$1,000
	(Appropriation of income for purchase of refrigerating plant.)	
1,000	Savings Account.	
	Bank Account.....	1,000
	(To set aside appropriation in special Savings account.)	

The above entries should be made periodically until the necessary amount has been raised.

DEBIT.		CREDIT.
\$5,000	Bank Account.	
	Savings Account.....	\$5,000
	(To withdraw fund from Savings account, making it available for the purchase of refrigerating plant.)	
5,000	Refrigerating plant.	
	Bank Account.....	5,000
	(For purchase of plant.)	
5,000	Reserve for Additional Equipment.	
	Surplus.....	5,000
	(To close Reserve account into Surplus.)	

The required Ledger accounts would be:

SAVINGS ACCOUNT.

DEBIT:	CREDIT:
1. With the periodical deposits to apply on the purchase of the refrigerating plant.	1. With the amount withdrawn for the purpose of expansion.

Any remaining balance should then be carried to the regular checking account by a credit to this account and a debit to the Bank Account.

REFRIGERATING PLANT.

DEBIT:	CREDIT:
1. With cost of new equipment at the time of purchase.	1. With the total book value of any part of the refrigerating plant sold or disposed of otherwise.

RESERVE FOR ADDITIONAL EQUIPMENT.

DEBIT:	CREDIT:
1. With the purchase price of new equipment covered by this reserve. (Credit to Surplus.)	1. With amounts periodically deposited in the Savings account for the purpose of expansion.

The balance of this account should be carried to the Surplus Adjustment account.

ADDITIONAL EQUIPMENT APPROPRIATION.

DEBIT:	CREDIT:
1. At the close of the period with the proportion to apply to the purchase of additional equipment.	1. With the debit balance at the close of the fiscal year. (Debit Loss and Gain.) ³

It is suggested that instead of carrying the reserve set up for the purpose of expansion to the Sinking Fund Reserve account, these accounts just illustrated be set up, in order that the books may reveal the entire history of the expansion. As before stated, the sinking fund should be an amount of cash actually set aside to liquidate a fixed liability at some future date. It should never be maintained for the purpose of defraying current expenses.

THE NATURE OF BOOKKEEPING.

In order that the procedure herein described may be more clearly understood the nature of bookkeeping is briefly discussed here.⁴

The Standard Dictionary defines bookkeeping as follows:

The art, method, or practice of recording business transactions distinctly and systematically in blank books provided for the purpose, so as to show goods and moneys received, disposed of, and on hand; the credits given, and the assets, liabilities, and general status of the business, person, or house.

If bookkeeping is "the art of recording business transactions," the account must be considered the material expression of this art, since all bookkeeping eventually centers in the construction of certain accounts which will reflect the result of business transactions.

For the purpose of recording and expressing the "general status of the business," accounts are classified as:

Asset Accounts: Representing all values which are owned and invested in the business; or earned, although not received, and those which have been expended for the benefit of a future period.

Liability Accounts: Representing all debts to outsiders due and now payable, due but not yet payable, and incurred to become due and payable at some future date.

Net Worth Accounts: Representing the original proprietorship and the effects of the operations on the proprietorship.⁵

Since Asset, Liability, and Net Worth accounts are representative of the actual properties themselves, these names are used to designate the properties, as well as their representative accounts.

Since the Assets are all that are owned and the Liabilities are all obligations to outsiders, the net worth must of necessity be the difference between the first two, or the rights of the proprietorship to the excess thus determined. The following statement, therefore, shows the equality existing between the total assets on the one side and the sum of the liabilities and net worth on the other.

³ Care should be exercised that this balance be transferred to Loss and Gain only after the net profit has been determined, as shown by the form illustrated on pp. 35 and 36.

⁴ Bookkeeping as discussed herein is limited to what is known as the double-entry method.

⁵ Income and Expense accounts are Net Worth accounts of a temporary nature. They are fully described on pages 23 to 30 for the purpose of showing the details of the operations and their ultimate effect on net worth.

$$\text{ASSETS} = \text{LIABILITIES} + \text{NET WORTH.}$$

All accounts being included in one of these groups, it is evident that all transactions must be considered in the light of their effect on the respective groups.

It is also evident that any transaction affecting one of the groups must likewise produce an equal net change in the other groups, except in a few instances when the transaction by its nature effects a change in the detail of one of the three groups and does not change the total of the affected group. We may classify these changes as:

Increase or decrease in assets.

Increase or decrease in liabilities.

Increase or decrease in net worth.

Transfer between items within any one group.

The customary bookkeeping names for these changes are "debit" and "credit." These same titles are used to show the side of the account on which the entry is made, debit being used for the left-hand side and credit for the right-hand side. Keeping these names in mind, the statement changes may be classified as follows:

DEBIT:	CREDIT:
(1) Increase in assets.	(1a) Decrease in assets.
(2) Decrease in liabilities.	(2a) Increase in liabilities.
(3) Decrease in net worth.	(3a) Increase in net worth.

It may be well to consider some of the more usual transactions which will arise in a business, and to note the way in which they affect our statement, and the classification shown above.

(1) Capital stock issued upon payment of cash. The result is an increase in the asset Cash and a corresponding increase in the Net Worth account Capital Stock. Using the above table, the transaction would be entered by a debit to Cash (1) and a credit to Capital Stock (3a).⁶

(2) Capital stock paid for by a note. The result is an increase in the asset Notes Receivable, and an equal increase in the Net Worth account, Capital Stock. Therefore, debit Notes Receivable (1) and credit Capital Stock (3a).

(3) A note receivable is paid in cash, without interest. There is an increase in the asset Cash and a decrease in the asset Notes Receivable. This is one of the transactions described as being a transfer affecting the detail of one of the three parts of the business statement, and not in any way changing the totals of the part. Being both an increase and a decrease in asset values, we must debit Cash (1), the asset increased, and credit Notes Receivable (1a), the asset decreased.

(4) Purchase of merchandise for cash. The asset Merchandise has increased; the asset Cash has decreased. Applying our table we have a debit to Merchandise (1) and a credit to Cash (1a).

(5) Purchase of merchandise on account. We have an increase in the asset Merchandise and an increase in the liability Accounts Payable; therefore, we will debit Merchandise (1), and credit Accounts Payable (2a).

(6) Merchandise sold for cash. There is an increase in the asset Cash and a decrease in the asset Merchandise. Debit Cash (1) and credit Merchandise (1a).⁷

(7) Merchandise sold on account. There is an increase in the asset Accounts Receivable and a decrease in the asset Merchandise. Debit Accounts Receivable (1) and credit Merchandise (1a).

⁶ All numbers shown in parentheses thus (3a) refer to the number of entry in the table.

⁷ Sales of merchandise or product actually affect two parts of our statement; i. e., that part of the sale price which represents the actual cost of the merchandise is a decrease in the asset, while the part representing profit is an increase in the net worth. These sales in actual practice are credited to Merchandise Sales and closed into Loss and Gain account at the end of the fiscal period.

(8) Employee is paid wages in cash. There is a decrease in the Net Worth and a decrease in the asset Cash. Wages are a cost of operation and therefore decrease the net worth. They are an expense as distinguished from income. Debit Labor (temporary Net Worth account) (3a) and credit Cash (1a).

After this manner, all transactions can be analyzed and classified to indicate the proper entry to be made.

Again referring to our statement, $\text{Assets} = \text{Liabilities} + \text{Net Worth}$, and to the discussion and illustrations which follow the statement, it should be noted that every transaction is composed of two parts, the debits and the credits, and that these two parts are always exactly equal and opposite in their effect.

If, then, we start with any statement, the two sides of which must be equal, and every transaction affecting this statement has its two sides equal, the two sides of the result must be equal. As the sides are called in bookkeeping debit side and credit side, or debit and credit, respectively, we may formulate the following rule: The debits and credits by which any transaction is recorded must be equal.

In this discussion we have considered only the three elements assets, liabilities, and net worth, and have classified the transactions as affecting two or more of these elements. In observing the changes in net worth, there are other effects to be considered besides the question that a change has occurred, and the total amount of such change.

It would be possible to discover this effect (in total) by recording the increases and decreases directly in the Net Worth account. However, when we attempt to discover the reasons for the increase or decrease in the total net worth, we are at a loss to do so, for our records have not been arranged so that results can be collected with proper regard to the relevant cause.

For this reason it is desirable that we introduce another series of accounts called Income and Expense accounts, which are in reality subdivisions of the Net Worth accounts.

Into these accounts are entered the various changes which are the result of the business operations, and which either increase or decrease the net worth, the Income accounts showing the increases and the Expense accounts showing the decreases. The net results of these accounts will show, then, the effect, increase or decrease, on the net worth of the business.

To arrive at the net result of these operations the various Expense accounts should be closed, their total being carried as a debit to the Loss and Gain account and the various Income accounts carried as a credit to the same account. The resulting balance of the Loss and Gain account is the net income or loss for the period, which result should be carried to the Surplus or Deficit accounts by order of the Board of Directors if the concern is a corporation or association, or to the proprietorship account if owned by a partnership or individual.

It will be noted that in making the annual entries to the debit and credit of this account, all the Income and Expense accounts will be balanced or closed. Accounts so closed should be ruled in red ink so that the year's business will be kept separate and distinct from that of the succeeding year.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 866

Contribution from the Bureau of Chemistry

CARL L. ALSBERG, Chief



Washington, D. C.



August 24, 1920

PICKERING SPRAYS.

By F. C. COOK,¹ *Physiological Chemist,
Insecticide and Fungicide Laboratory.*

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INTRODUCTION.

When, in 1916, the price of copper sulphate (bluestone or blue vitriol) rose to 25 and 30 cents a pound in certain parts of the country, the United States Department of Agriculture began to receive many inquiries as to the possibility of controlling certain fungous diseases of fruits and vegetables, either by using sprays other than those containing copper or by reducing the amount of copper sulphate used per given amount of spray. Past work having failed to show any fungicides which could replace the copper sprays for certain important plant diseases and the search for a new spray appearing rather unpromising, it seemed advisable to seek a copper spray which was more effective per unit of copper than the standard Bordeaux mixture and at the same time not so caustic as to injure vegetation. Accordingly, the Bureau of Chemistry, in cooperation with the Bureau of Plant Industry and the Maine Agricultural Experiment Station, undertook an investigation to determine the comparative efficacy of the so-called Pickering sprays, which had been

¹ The author wishes to express his appreciation of the cooperation he received from J. K. Haywood, Bureau of Chemistry; from W. B. Clark, H. A. Edson, L. H. Evans, W. A. Orton, J. W. Roberts, E. S. Schultz, C. L. Shear, M. B. Waite, E. Wallace, and R. B. Wilcox, of the Bureau of Plant Industry; from Donald Folson, W. A. Morse, G. B. Ramsey, and C. D. Woods, of the Maine Agricultural Experiment Station; and from Franklin Chambers, Superintendent of Whitesbog, Hanover Farms, N. J., and J. E. Sullivan, Superintendent of Aroostook Farm, Maine.

tested to a limited extent in England, where laboratory tests indicated that they were superior to the Bordeaux sprays (3, 4).¹ Pickering sprays, sometimes called Pickering limewater sprays, are prepared by mixing saturated limewater with dilute solutions of copper sulphate, and contain their copper in the form of basic copper sulphates.

RESULTS OF PREVIOUS INVESTIGATIONS.

FUNGICIDAL ACTION.

Bedford and Pickering (3, 4) claimed that the fungicidal action of Bordeaux depends upon the re-formation of copper sulphate by the action of carbon dioxid from the air. They believed that the excess of lime present in Bordeaux is carbonated before the copper, and held that since the fungicidal action depends upon the carbonation of the copper and the re-formation of copper sulphate, the excess lime of Bordeaux delays the action. These investigators stated that basic sulphates of copper are produced by the action of lime on copper sulphate, and that the basic sulphates vary in composition according to the proportions of lime and copper used. Most of the basic sulphates are complex, and contain, in addition to the elements essential in a basic sulphate of copper, calcium sulphate or calcium oxid, sometimes both. For present purposes the calcium sulphate in these compounds need not be considered. The basic sulphates of copper, being practically insoluble in water, can of themselves have little or no fungicidal action, but when exposed to the carbon dioxid of the air they are gradually decomposed to form copper carbonate and copper sulphate. The copper carbonate, being insoluble, is incapable of energetic action. According to Bedford and Pickering, the substances which are formed in the so-called Pickering sprays by the action of lime on copper sulphate, omitting the calcium sulphate present, are:

Formula A.— $4 \text{ CuO}, \text{SO}_3$ (or $10 \text{ CuO}, 2.5 \text{ SO}_3$).

Formula B.— $5 \text{ CuO}, \text{SO}_3$ (or $10 \text{ CuO}, 2 \text{ SO}_3$).

Formula C.— $10 \text{ CuO}, \text{SO}_3$.

Formula D.— $10 \text{ CuO}, \text{SO}_3, 3 \text{ CaO}$ (ordinary Bordeaux).

Formula E.— $\text{CuO}, 2 \text{ CaO}$ (or $10 \text{ CuO}, 20 \text{ CaO}$) (existence doubtful).

Formula F.— $\text{CuO}, 3 \text{ CaO}$ (or $10 \text{ CuO}, 30 \text{ CaO}$).

The following equations² express the changes which these substances undergo when acted upon by carbon dioxid in the laboratory, the equations being so arranged as to represent the results when the same initial weight of copper sulphate is taken in each case. The

¹ The figures in parenthesis throughout this bulletin refer to the bibliography on page 46.

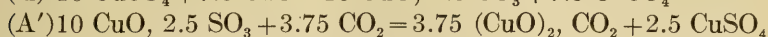
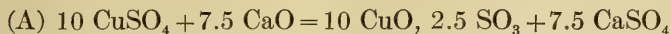
² The formulas are expressed in terms of the English imperial gallon, which weighs 10 pounds, while the U. S. gallon weighs 8.3389 pounds, and the English fluid ounce, which is equivalent to 1/20 pint, or 28 cc., while the U. S. fluid ounce is equivalent to 1/16 pint, or 29.6 cc.

actual weight of pure lime (calcium oxid) and the approximate volume of clear limewater which would contain this lime are also given in each case.

FORMULA A (4 CuO, SO₃).

Proportions required: Crystallized copper sulphate 1, lime 0.169 (6:1); or copper sulphate 1 ounce,¹ limewater 134 ounces.²

REACTION.

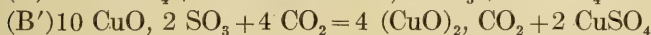
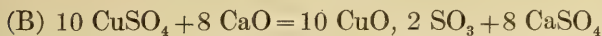


This formula represents a 25 per cent re-formation of copper sulphate.

FORMULA B (5 CuO, SO₃).

Proportions required: Crystallized copper sulphate 1, lime 0.18 (5.56:1); or copper sulphate 1 ounce,¹ limewater 143 ounces.²

REACTION.

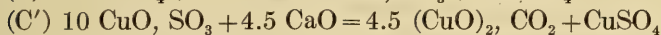
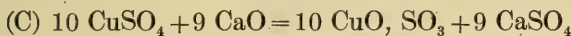


This formula represents a 20 per cent re-formation of copper sulphate.

FORMULA C (10 CuO, SO₃).

Proportions required: Copper sulphate 1, lime 0.203 (5:1); or copper sulphate 1 ounce,¹ limewater 161 ounces.²

REACTION.

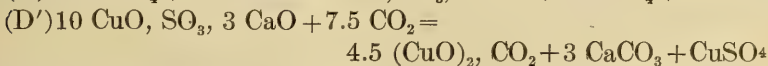
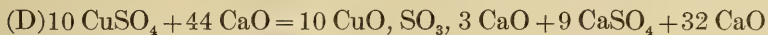


This formula represents a 10 per cent re-formation of copper sulphate.

FORMULA D (ORDINARY BORDEAUX MIXTURE).

Proportions required: Equal weights of copper sulphate and lime; or copper sulphate 1 ounce,¹ limewater 800 ounces.²

REACTION.



This formula represents a 10 per cent re-formation of copper sulphate.

¹ Avoirdupois.

² Fluid imperial ounces.

The results of their laboratory tests, in which the re-formed copper sulphate was determined after carbon dioxid had been passed through the various basic sulphates, led Bedford and Pickering to believe that the Formula A spray, re-forming 40 per cent of the copper sulphate, was from 12 to 15 times as effective as ordinary Bordeaux mixture (Formula D), which re-formed 2.8 per cent of the copper sulphate, and that the Formula C spray, re-forming 22 per cent of the copper sulphate, was about 8 times as effective as the standard Bordeaux (Formula D).

These investigators (4) stated also that, "the efficacy of a fungicide must not be estimated by the amount of copper contained in it, but by the amount which becomes soluble and therefore available for fungicidal action. Nor should the efficiency of a spray be judged by the visible deposit left on the leaves, for even if it were composed entirely of copper compounds it does not follow that it would be more efficacious than some other deposit which might be invisible. In most cases the deposit consists largely of material which is quite inefficient and may be detrimental to fungicidal action, as is the lime which constitutes four-fifths of the deposit visible after spraying with ordinary Bordeaux mixture." Later they reported that the idea that the fungicidal action of standard Bordeaux spray does not commence until several days after its application had been definitely disproved, and that the effects of the application of Bordeaux do not become visible at once because time is necessary for the decay of the tissues, which is the case even when a copper salt in solution is applied, but that the excess of lime in ordinary Bordeaux causes the fungicidal action to proceed more slowly. Pickering, however, believed that in ordinary or standard Bordeaux made with milk of lime the copper reacts and undergoes on the tree the changes given under the reaction for Formula D (p. 3).

Swingle (23), Sicard (22), Bell and Taber (5), Vermorel and Dantony (24), and others have discussed the chemical composition of standard Bordeaux sprays, which are prepared by mixing a solution of copper sulphate with milk of lime. These two ingredients are brought together in various ways, and the manner of mixing undoubtedly affects the chemical and physical properties of the spray. The details of the many theories covering the chemical reactions which take place when copper sulphate and calcium hydrate are mixed need not be considered here:

Opposed to the belief held by Pickering and others that the copper of Bordeaux is slowly made active by the carbon dioxid of the air are the statements by Lutman (14) that Bordeaux mixture is fungicidal immediately upon application. This writer considers that the lime particles in Bordeaux have fungicidal properties. Swingle (23), in 1896, advanced a series of ideas as to possible methods

whereby the copper of Bordeaux prevented fungous infection of plants. Gimingham (10) and Barker and Gimingham (1, 2) do not accept the theory of Pickering that the carbon dioxid of the air renders the copper soluble in Bordeaux, but believe that the permeable cell walls of the spores absorb copper from insoluble copper compounds in the spray.

In 1902 Clark (8) stated that the process of rendering soluble portions of the copper hydrate ($\text{Cu}(\text{OH})_2$) of Bordeaux mixture, which under orchard conditions is of fungicidal value, is accomplished chiefly by the solvent action of the fungus spores, which have the power to dissolve enough copper to kill themselves. The host plant has a certain power of dissolving copper hydrate deposited on its leaves.

PHYSICAL PROPERTIES.

A spray must so distribute the copper compound it contains as to completely cover the trees or plants in a thoroughly uniform manner and must possess the proper adhesive properties. If either of these physical properties is lacking, the spray fails to accomplish its purpose.

Various settling tests with Bordeaux prepared in different ways have been made, and numerous adhesives have been tried. Hawkins (12), who gives a detailed description of such tests, states that Pickering sprays remain in suspension better than ordinary Bordeaux. Lutman (13), in his data, which include descriptions of the precipitation membranes formed in freshly prepared Bordeaux, states that the slow settling properties and the presence of the precipitation membranes in freshly prepared Bordeaux are in a great measure responsible for its superiority as a protective agent against fungous diseases. This investigator studied the areas covered by 1 cubic centimeter of the various sprays tested on glass slides, as a result of which he concludes that "very dilute solutions such as Pickerings possess a greater covering power for the amount of materials used."

The physical properties of the Pickering, or limewater Bordeaux, sprays are not described by Pickering, but have been studied by Lutman (14) and by Butler (6). Butler, who has investigated the formation of sphere crystals in various copper sprays, claims that the rate at which they form depends on the concentration and temperature of the mixture. Both of these investigators state that the film membranes of the Pickering sprays do not deteriorate as do those in a regular Bordeaux spray, and that the sphere crystals are not formed in Pickering sprays, even after long standing. This is an important point, as the formation of such crystals signifies a breaking down of the precipitation membranes and a deterioration of the spray.

GENERAL CONSIDERATIONS.

Butler (7) states that freshly prepared Pickering spray has a light-blue color, which becomes deep blue on standing. He found a neutral or acid Bordeaux, such as the Pickering sprays, to act more quickly than ordinary Bordeaux, and reported that the Pickering spray was less injurious to grapes than ordinary Bordeaux. He states that the toxic value of the unit copper is the same in acid, neutral, and alkaline Bordeaux, but is more available for immediate action in the Pickering than in the ordinary Bordeaux sprays.

According to McAlpine (15), who compared the results of Pickering with those of standard Bordeaux sprays on apple trees, the two varieties are equally effective in controlling black spot (*Fusicladium dendriticum*). The limewater Bordeaux adhered just as well as the standard Bordeaux, and had the additional advantages of being free from gritty particles, of acting at once on the spores of the fungus, and of containing a much smaller percentage of bluestone. The check trees gave 92.5 per cent of good fruit, indicating that the black spot was not sufficiently severe to give definite results.

F. de Castella (9) states that Pickering's claims concerning the greater efficacy of the limewater sprays are not borne out in practice. He reports that after extensive trial they have been found decidedly inferior to 2 per cent Bordeaux and that the use of Pickering sprays can not be recommended. He considers the Woburn or Pickering paste sold in England to be satisfactory but not superior to Bordeaux. The greater solubility of the tetra-cupric sulphate seems to be a defect rather than an advantage according to this writer, for the reason that, while more active at first, it is removed by heavy rains more readily than the ordinary Bordeaux deposit, thus rendering the duration of the protection insufficient. No data are given by this writer to substantiate his claims.

PURPOSE OF PRESENT INVESTIGATION.

If the results obtained by Pickering in the laboratory in England hold true under field conditions in America, it is obvious that a great saving in copper in this country may be effected. This investigation was planned, therefore, for the purpose of outlining a practical method of preparing a copper fungicide which would be more effective per unit of copper than standard Bordeaux. The experiments were conducted with the following primary objects in view:

- (1) To determine whether sprays made in accordance with the various Pickering formulas (p. 3) were effective when applied under American field conditions.

- (2) To ascertain how much copper in the form of the different Pickering formulas is required per given quantity of spray to insure effective control of fungous diseases.

(3) To compare the fungicidal values of certain of the more promising Pickering sprays with those of standard Bordeaux mixture per unit of copper.

(4) To determine the injurious action of the more promising Pickering sprays on various kinds of vegetation as compared with that of standard Bordeaux.

(5) To compare the adherence of Pickering sprays with that of standard Bordeaux.

PREPARATION OF SPRAYS USED.

Pickering sprays made according to Formulas A and C (p. 3) were used in such proportions that the finished sprays prepared by Formula A would contain the equivalent of 0.64, 0.38, 0.13, and 0.065 per cent of copper sulphate, and those prepared by Formula C, 0.36, 0.23, and 0.115 per cent of copper sulphate. In making the stock solutions of limewater and copper sulphate these directions, outlined by Bedford and Pickering (4), were followed:

Dissolve the copper sulphate by suspending it in a piece of sacking, near the top of the water, in a wooden or earthenware container. Place not less than 2 or 3 pounds of some good quicklime (CaO) in a wooden container, slake with a little water, and add the desired amount of soft water. After making a smooth paste, add water, stir the lime and water two or three times, and let settle. Cover the container. Carbonate of lime found on top of the water does no harm. Run off the desired amount of the clear limewater, and mix with the required amount of copper sulphate solution. Test to be sure that all the copper has been combined with lime, and dilute to the required volume with water. To test for free copper, put a few drops of a solution of ferrocyanide of potash in a white saucer with water and drop into this some of the clear liquid obtained after the limewater Bordeaux has settled. If a brownish-red coloration appears, it indicates that copper remains in solution, a little more limewater must be added, and the solution retested.

To prepare Pickering (A)¹ sprays containing in the finished product the equivalent of—

0.64 per cent copper sulphate: Mix enough of the stock solution of copper sulphate (prepared so that 1 gallon is equivalent to 1 pound of copper sulphate) to obtain 2 pounds, 10.7 ounces of crystallized copper sulphate with 42.88 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

0.38 per cent copper sulphate: Mix enough of the stock solution of copper sulphate to obtain 1 pound, 9.3 ounces of crystallized copper sulphate with 25.47 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

0.13 per cent copper sulphate: Mix enough of the stock solution of copper sulphate to obtain 8.67 ounces of crystallized copper sulphate with 8.71 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

0.065 per cent copper sulphate: Mix enough of the stock solution of copper sulphate to obtain 4.33 ounces of crystallized copper sulphate with 4.36 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

¹ Throughout this bulletin capital letters in parenthesis following "Pickering" indicate the formula used in making the spray.

To prepare Pickering (C) sprays containing in the finished spray the equivalent of—

0.36 per cent copper sulphate: Mix enough of the stock solution of copper sulphate to obtain 1 pound. 8 ounces of crystallized copper sulphate with 38.98 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

0.23 per cent copper sulphate: Mix enough of the stock solution of copper sulphate to obtain 15.3 ounces of crystallized copper sulphate with 18.52 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

0.115 per cent copper sulphate: Mix enough of the stock solution of copper sulphate to obtain 7.7 ounces of crystallized copper sulphate with 9.26 U. S. gallons of the stock limewater, and make up the total volume to 50 U. S. gallons.

Samples of water used in the various localities for the preparation of Pickering and Bordeaux sprays, analyzed by the Water Laboratory of the Bureau of Chemistry, contained very little lime or any other constituent that might interfere with the preparation of sprays, such as the Pickering sprays, which are made according to definite formulas and are said to depend for their activity on the presence of definite compounds, the basic sulphates of copper. According to the tests of Bedford and Pickering (3, 4), slight variations in the amounts of limewater employed result in the formation of different basic sulphates of copper, each of which functions as a fungicide in a characteristic way.

In slaking lime it is important to add just enough water to make it heat, after which water is added slowly to keep the lime from burning. When the reaction nears completion more water is added to make a paste. Finally, when the total amount of water required has been added, the solution is stirred to form saturated limewater.

RESULTS OF INVESTIGATION.

POTATOES.

BLIGHT CONTROL AND YIELD.

PICKERING AND STANDARD BORDEAUX SPRAYS IN 1916.

Six acres of Green Mountain potatoes in northern Maine (near the Aroostook Farm at Presque Isle) were selected for these experiments. As the sprayer was made to spray four rows at a time, the field was divided into four-row plats which, in turn, were subdivided into 200-foot lengths. Since the field was 800 feet long, four subdivisions were made in each group of four rows. A certain spray was applied to the first and third 200-foot plats, another one to the second and fourth 200-foot plats, etc. Thus each spray was applied to one plat in the front and to one in the rear of the field. The plats were so arranged that each four-row plat where any particular spray was being tested had a four-row plat of Bordeaux-sprayed potatoes on one side and a four-row check plat on the other.

Seven Pickering sprays were tested. Four (those used on plats 1, 2, 3, and 4) were made according to Formula A, while three (those

used on plats 5, 6, and 7) were made by Formula C. All the Pickering sprays were applied with a hand-pump apparatus on July 19 and August 2, 10, and 17. Bordeaux was applied on these days, and also on July 26. Thus the Pickering sprays were applied four and the Bordeaux five times. Readings for blight, both early and late, were made by three observers working independently, those for the late blight (*Phytophthora infestans*) being made on the two middle rows of each plat. The average figures obtained from two observations by each of these individuals are recorded, in terms of the estimated percentage of the total foliage infected, in Table 1. The potatoes from the several plats were picked up separately and weighed, the yield results thus obtained being given in Table 1.

TABLE 1.—*Effect of various sprays on blight and yield of potatoes (northern Maine, 1916).*

Plat No.	Spray used.	Copper sulphate in spray used.	Early blight.		Late blight.		Yield of tubers. ¹	
			Front of field.	Rear of field.	Front of field.	Rear of field.	Front of field.	Rear of field.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Pounds.	Pounds.
.....	Bordeaux, 5-5-50.....	1.25	52	59	7	4	1,189	1,026
6.....	Pickering (C).....	.115	67	73	40	5	1,165	957
Check.....	.....		66	80	60	7	1,202	1,009
5.....	Pickering (C).....	.23	64	78	43	5	1,221	963
.....	Bordeaux, 5-5-50.....	1.25	59	78	5	2	1,225	1,027
4.....	Pickering (A).....	.065	63	86	53	6	1,170	915
Check.....	.....		68	83	53	7	1,189	957
3.....	Pickering (A).....	.13	65	78	13	5	1,187	901
.....	Bordeaux, 5-5-50.....	1.25	50	41	7	2	1,252	1,260
7.....	Pickering (C).....	.36	61	58	36	6	1,283	1,260
Check.....	.....		67	68	54	21	1,309	1,335
1.....	Pickering (A).....	.64	64	55	27	4	1,260	1,426
.....	Bordeaux, 5-5-50.....	1.25	56	58	4	3	1,276	1,386
2.....	Pickering (A).....	.38	63	61	21	7	1,313	1,208
Check.....	.....		59	64	21	12	1,220	1,190
2a.....	Pickering (A) and rosin-fish-oil soap.	.38	72	70	5	3	1,179	1,016

¹ Determinations were made on 200-foot depth of field, four-row plats.

The blight in 1916 was not severe. The late blight on the potatoes under observation was very irregular, being marked in certain parts of the front of the field, particularly on the check plats, while the rear showed but little. On August 24 the vines in plat 1 and in those sprayed with Bordeaux were green, while those in all the other plats had died.¹ The best results for the control of late blight (*Phytophthora infestans*) on potatoes were obtained with standard Bordeaux, 5-5-50. The average estimated percentage of late blight on all of the plats sprayed with Bordeaux was $4\frac{1}{4}$, the extremes being 2 and 7.

The average yield for all of the plats sprayed with standard Bordeaux was 1,205 pounds of tubers, and for the check plats 1,176 pounds. Plat 1, sprayed with the Pickering (A) spray, containing 0.64 per cent of copper sulphate, averaged 1,343 pounds of tubers, and showed 27 and 4 per cent of blight in the front and rear portions

¹ A portion of this field was sprayed commercially by the owner, starting with a Bordeaux, 4-4-50, and finishing with a Bordeaux, 7-7-50 or 8-8-50. Neither the length of life of the vines nor the yield was increased by this treatment.

of the field, respectively. Plat 2a, receiving the Pickering spray which contained 0.38 per cent of copper sulphate and was mixed with rosin-fish-oil soap, showed 5 and 3 per cent of blight, and a yield of 1,098 pounds, while plat 2, receiving the same spray without the soap, showed 21 and 7 per cent of blight, and a yield of 1,261 pounds. Plat 3, receiving Pickering spray with an 0.13 per cent copper sulphate content, showed 13 and 5 per cent of blight, while plat 7 gave 36 and 6 per cent for blight. All the Pickering-sprayed plats were next to a check plat, while those receiving the Bordeaux were protected by sprayed plats on each side.

No rotten tubers were found on any of the plats. As is often the case, some variation occurred in the yields from different portions of the field. The vines of the check plats were not injured by driving through the plats, a factor of some importance in view of the fact that the spray cart was driven twice through some of the sprayed plats and four times through others when each spray was applied.

It is interesting to note that the average yields of the Pickering-sprayed plats just discussed varied with the percentage of copper sulphate present in the spray. The increased yield of the sprayed vines over that of the unsprayed vines was small, because of the dry weather and the early date at which the vines died.

The weak Pickering sprays (containing 0.23 per cent of copper sulphate or less) did not give satisfactory blight readings or results for yield. While the 0.64, 0.38, and 0.36 per cent copper sulphate Pickering sprays gave little indications of controlling the late blight in the front plats, they showed some control on the rear plats, and all the yields were satisfactory. No differences in the action of the Pickering (A) and Pickering (C) sprays were noticed. The copper in these sprays did not appear to be 12 times as effective as that in the standard Bordeaux sprays, but per unit of copper present the Pickering sprays looked promising. It was accordingly decided to try Pickering sprays containing a higher percentage of copper sulphate the following year.

PICKERING AND BORDEAUX SPRAYS IN 1917.

The arrangement of the plats adopted in 1916 (p. 8) was varied somewhat in 1917, in that the plats were arranged in triplicate and the various plats receiving the same treatment were placed in three different sections of the field.

The copper sulphate content of the Pickering sprays tested varied from 0.3 to 0.7 per cent (Table 2). Rosin-fish-oil soap, 2 pounds to 50 gallons, was added to the Pickering (A) spray applied to plat 12, and dry arsenate of lead, 1 pound to 50 gallons, to the Pickering (A) spray applied to plat 13 and to the Pickering (C) spray applied to plat 14. Each of these three sprays contained 0.5 per cent of cop-

per sulphate. Green Mountain (Norcross strain) potatoes, grown on new land, were sprayed six times during the season, using a Watson sprayer, after the vines were 10 or 12 inches above the ground.

Portions of the two middle rows of each plat were read for blight and used for the yield data. The blight readings (Table 2) are the averages of the last readings of four individuals who worked independently of one another. The results obtained with Bordeaux spray (Pl. I, fig. 1) are more favorable than those secured from using the Pickering spray, with the exception of that applied to plat 1, where they were equally as good (Pl. I, fig. 2). The Pickering sprays which contained less than 0.5 per cent of copper sulphate did not control the blight as effectively as the standard Bordeaux and the Pickering sprays containing 0.6 or 0.7 per cent of copper sulphate.

TABLE 2.—*Effect of various sprays on blight and yield of potatoes (northern Maine, 1917).*¹

Plat No.	Spray used.	Copper sulphate in spray used.	Late blight.	Yield of tubers.	Rotten tubers.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Pounds.</i>	<i>Per cent.</i>
1.....	Pickering (A).....	0.7	44	406	12
Check.....	Bordeaux, 5-5-50.....	1.25	45	384	14
2.....	Pickering (A).....	0.6	57	347	12
Check.....	Bordeaux, 5-5-50.....	1.25	52	409	13
3.....	Pickering (C).....	0.6	41	414	10
Check.....	Bordeaux, 5-5-50.....	1.25	85	321	10
4.....	Pickering (A).....	0.5	48	404	10
Check.....	Bordeaux, 5-5-50.....	1.25	42	415	11
5.....	Pickering (C).....	0.5	95	335	10
Check.....	Bordeaux, 5-5-50.....	1.25	53	392	12
6.....	Pickering (A).....	0.4	42	393	10
Check.....	Bordeaux, 5-5-50.....	1.25	88	301	10
7.....	Pickering (C).....	0.5	53	349	14
Check.....	Bordeaux, 5-5-50.....	1.25	43	325	8
8.....	Pickering (A).....	0.4	84	296	12
Check.....	Bordeaux, 5-5-50.....	1.25	67	355	10
9.....	Pickering (C).....	0.4	37	415	11
Check.....	Bordeaux, 5-5-50.....	1.25	96	309	7
10.....	Pickering (A).....	0.5	76	381	11
Check.....	Bordeaux, 5-5-50.....	1.25	39	399	8
11.....	Pickering (C).....	0.3	96	320	9
Check.....	Bordeaux, 5-5-50.....	1.25	63	337	14
12.....	Pickering (A) and rosin-fish-oil soap.....	0.5	41	451	11
Check.....	Bordeaux, 5-5-50.....	1.25	96	270	9
13.....	Pickering (A) and lead arsenate.....	0.5	56	345	11
Check.....	Bordeaux, 5-5-50.....	1.25	41	366	17
14.....	Pickering (C) and lead arsenate.....	0.5	96	294	11
Check.....	Bordeaux, 5-5-50.....	1.25	56	406	11
15.....	Pickering (A).....	0.5	42	430	13
Check.....	Bordeaux, 5-5-50.....	1.25	96	270	9
16.....	Pickering (C).....	0.5	57	358	10
Check.....	Bordeaux, 5-5-50.....	1.25	44	396	16
17.....	Pickering (A).....	0.5	96	294	11
Check.....	Bordeaux, 5-5-50.....	1.25	56	406	11

¹ Determinations were made on two rows, each 300 feet long.

The total yield results for plats 1, 2, and 3, treated with Pickering sprays, and for the corresponding Bordeaux-sprayed and check plats are as follows: Pickering, 1,219 pounds; Bordeaux, 1,213 pounds; and check, 1,003 pounds. Plats 4 and 5, to which the Pickering spray having an 0.5 per cent copper sulphate content was applied, yielded 741 pounds of tubers; the corresponding Bordeaux-sprayed plats, 718 pounds; and the check plats, 597 pounds. The plats

treated with Pickering sprays containing less than 0.4 per cent of copper sulphate yielded less than the corresponding Bordeaux-sprayed plats but more than the check plats. The yield of tubers from the sprayed plats showed an increase of from 30 to 40 per cent over that from the unsprayed plats.

A high proportion of rotten tubers was found on all the plats. This was due principally to the wet weather, but partially to the late start made in applying the sprays. The percentage of rotten tubers from the various plats is too variable to permit of any definite conclusions. The tubers from the check plats showed no more rot than those from the sprayed plats. Barrels of potatoes from several of the plats treated with Pickering and Bordeaux sprays, as well as from the check plats, were stored in a potato cellar until February, 1918, when the tubers were sorted. The percentage of rot found among the potatoes from the various plats was very uniform.

In 1917 the blight was severe, and the land used for the experiments was uneven, which gave some of the plats a decided advantage over others. The results showed that a Pickering spray containing 0.7 per cent of copper sulphate is in all respects as efficient as a Bordeaux, 5-5-50, containing 1.25 per cent of copper sulphate. No differences were noted in the relative efficiency of the Pickering (A) and (C) sprays. While these sprays were not shown to be 12 times as effective as standard Bordeaux, the indications were that they were more efficient per unit of copper in the solution used than the Bordeaux mixture.

PICKERING AND BORDEAUX SPRAYS IN 1918.

Series 1.—Tests with Pickering (A) spray, containing 0.7 per cent of copper sulphate, were made on two farms in the vicinity of Presque Isle, as well as on the farm used in 1916 and 1917. Each spray was applied five times to acre plats, using a Watson sprayer, two nozzles per row, in two instances, and a new single-nozzle sprayer in the other. Twice during the season the vines were double sprayed.

The blight, while widespread in July, and threatening to do as much damage as in the previous season, was stopped by the dry weather during August. The blight readings on the vines, made by three individuals working independently, were low, 2 per cent or less, for the Pickering- and Bordeaux-sprayed plats. The check plats showed from 20 to 50 per cent of blight. Evidently, then, the Pickering sprays applied in 1918 checked the blight as effectively as did the Bordeaux mixture.

The yield results on two of the farms varied greatly, according to the location of the plats, because of an uneven distribution of manure and fertilizer over the fields. On the farm previously used for the



FIG. 1.—POTATO VINES SPRAYED WITH BORDEAUX, 3-3-50 (PLAT 55), AND UNSPRAYED (PLAT 54).



FIG. 2.—POTATO VINES SPRAYED WITH PICKERING SPRAY (LEFT OF STAKE 43) AND UNSPRAYED VINES (RIGHT OF STAKE 43).



FIG. 1.—POTATO VINES SPRAYED WITH BORDEAUX, 5-5-50 (PLAT B), AND WITH PICKERING SPRAY (PLAT I).



FIG. 2.—POTATO VINES SPRAYED WITH BARIUM-WATER SPRAY (PLAT 59) AND UNSPRAYED (PLAT 58).

experimental work, however, where the treatment of the soil was uniform, increased yields were obtained from the plats treated with the Pickering and Bordeaux sprays.

Series 2.—A second series of tests was conducted in northern Maine in 1918, using (1) a Bordeaux spray, (2) Pickering (A) and (C) sprays, (3) a spray in which the limewater was replaced by barium water, and (4) an 0.6 per cent solution of copper sulphate to which powdered arsenate of lead (1 pound to 50 gallons) had been added. In all cases the sprays were made to contain 0.6 per cent of copper sulphate. Green Mountain (Norcross strain) potatoes were first sprayed when the vines were 5 or 6 inches above the ground, after which they received five applications with a Watson sprayer, using two nozzles to a row. The results of this work are recorded in Table 3.

TABLE 3.—*Effect of various sprays on blight and yield of tubers (northern Maine, 1918).*

Plat No.	Spray used.	Copper sulphate in spray used.	Late blight.	Yield of tubers. ¹
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Pounds.</i>
Farm 1.....	Pickering (A).....	0.7	2.0	274
	Barium water.....	.7	1.0	277
	Bordeaux, 5-5-50.....	1.25	1.7	247
	Bordeaux, 4-4-50.....	1.0	1.0	276
	Bordeaux, 4-2-50.....	1.0	3.0	258
	Bordeaux, 4-1-50.....	1.0	2.7	277
Check.....			20-50	215
Farm 2.....	Pickering (A).....	.7	1.2	261
	Barium water.....	.7	1.6	264
	Bordeaux, 5-5-50.....	1.25	1.2	279
	Bordeaux, 4-4-50.....	1.0	1.5	243
	Bordeaux, 4-2-50.....	1.0	1.7	198
	Bordeaux, 4-1-50.....	1.0	1.8	222
Farm 3.....	Pickering (A).....	.7	1.3	227
	Barium water.....	.7	2.3	303
	Bordeaux, 5-5-50.....	1.25	2.0	224
	Bordeaux, 4-4-50.....	1.0	1.3	295
	Bordeaux, 4-2-50.....	1.0	1.9	370
	Bordeaux, 4-1-50.....	1.0	2.5	375
Farm 1 (2d series):				
1.....	Bordeaux, 5-5-50.....	1.25	.5	244
2 (check).....			33.0	235
3.....	Pickering (A).....	.60	1.7	241
4.....	Pickering (C).....	.60	1.3	251
5.....	Bordeaux, 2½-2½-50.....	.60	3.0	248
6.....	Barium water.....	.60	1.7	241
7.....	Copper sulphate and lead arsenate.....	.60	1.8	237
8.....	Bordeaux, 5-5-50.....	1.25	1.2	242
9 (check) ²			45.0	175

¹ Determinations made on two rows, each 150 feet long.

² Plat partially shaded.

The blight readings of all the plats sprayed were practically the same (1 to 3 per cent), while the vines on the check plats showed 33 and 45 per cent infection. The yields were remarkably uniform for all the plats, with the exception of the last check plat, which was shaded by the adjacent trees. The dry season and the fact that the vines were killed by frost on September 9 tended to reduce the increased yields which are usually obtained from sprayed plats. Here the Pickering sprays containing 0.6 per cent of copper sulphate

gave as good results as the Bordeaux sprays containing 1.25 per cent of copper sulphate. In fact, all of the sprays gave practically the same results. The only plats giving yields below 240 pounds were the two check plats and the one treated with copper sulphate and lead arsenate. The yield and blight readings were practically the same for the plats sprayed with the Pickering solution as for those sprayed with Bordeaux mixture (Plate II, fig. 1).

In Central Maine.—Separate plats of about $\frac{1}{2}$ acre each of Green Mountain and Rural New Yorker seed potatoes, in Foxcroft, Me., were treated with Pickering and barium-water sprays of 0.7 per cent copper sulphate content, and with reduced lime Bordeaux, 4-4-50, 4-2-50, and 4-1-50, sprays. The rest of the 8-acre field was sprayed with a standard Bordeaux, 5-5-50. Plats sprayed with standard Bordeaux were placed between the experimental plats. A spray wagon treating six rows at a time was used. As the vines were not sprayed until July 15, they were double sprayed at each spraying, or four times altogether. The results of these tests are given in Table 4.

TABLE 4.—*Effect of various sprays on late blight and yield of potatoes (Central Maine, 1918).*

Plat No.	Spray used.	Copper sulphate in spray.	Green Mountain.		Rural New Yorker.	
			Blight on vines.	Yield. ¹	Blight on vines.	Yield. ¹
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Pounds.</i>	<i>Per cent.</i>	<i>Pounds.</i>
1....	Pickering (A).....	0.7	Trace.	331	Trace.	324
2....	Barium water.....	.7	do.....	322	do.....	332
23....	Bordeaux, 4-4-50.....	1.0	do.....	285	do.....	285
4....	Bordeaux, 4-2-50.....	1.0	do.....	338	do.....	333
5....	Bordeaux, 4-1-50.....	1.0	do.....	381	do.....	319
6....	Bordeaux, 5-5-50.....	1.25	do.....	258	do.....	330

¹ Obtained from two rows, 150 feet long.

² A ledge of rock in this plat.

On the whole, the blight results were uniform and very low. Early in August a trace of blight appeared through this and other fields, but the dry August practically put an end to it. The yields of Green Mountain tubers varied somewhat, particularly at the lower end of the field where plats 5 and 6 were located, but plats 1, 2, and 4 gave practically the same yields. The Rural New Yorker potatoes were grown on a more uniform portion of the field, so that they showed uniform results, except in plat 3, where a ledge of rock reduced the yield. Only traces of blight were seen on the Rural New Yorker vines, which are much more rangy and stand up from the ground higher than the Green Mountain vines, making them less liable to infections of late blight.

BARIUM-WATER SPRAYS IN 1916.

It was thought that the greater solubility of barium hydrate over lime might be an advantage in the preparation of a spray like the

Pickering sprays. While barium hydrate costs much more than lime, barium, unlike lime, is dissolved, leaving no residue. Barium is said to possess some fungicidal powers which lime does not. Osterhout (16) noticed a peculiar contraction of certain species of *spirogyra* in 0.0001 molecular solution of barium chlorid, which was not produced by chlorid of lime or other salts.

A spray containing 0.38 per cent of copper sulphate was prepared by dissolving barium hydrate in water and adding the copper sulphate solution to the barium water. When necessary more barium water was added until no free copper was present, as determined by tests with potassium ferrocyanide.

In 1916 this spray was applied four times, while the regular 5-5-50 Bordeaux was applied five times. The plats sprayed with barium water were next to the check plats and the Bordeaux-sprayed plats were between two sprayed plats. The blight readings were: Barium-water-sprayed plats, 25 and 12 per cent; Bordeaux-sprayed plats, 12 and 10 per cent; check plats, 75 and 41 per cent. The yields of tubers were: Barium-water-sprayed plats, 1,142 and 1,052 pounds; Bordeaux-sprayed plats, 1,125 and 1,168 pounds; check plats, 1,058 and 1,138 pounds. In view of the fact that only 0.38 per cent of copper sulphate was present in the spray and but four applications were made, while the Bordeaux was applied five times, these results were sufficiently satisfactory to warrant additional tests.

BARIUM-WATER SPRAYS IN 1917.

In 1917 a barium-water spray made to contain 0.7 per cent of copper sulphate was tested. The average percentage of late blight on the vines was: Check plat, 76 per cent; barium-water-sprayed plat, 21 per cent; Bordeaux-sprayed plat, 13 per cent. The yield of tubers and percentage of rot from the two middle rows of each plat, each row being 100 feet long, were: Standard Bordeaux-sprayed plat, 148 pounds, 8 per cent rot; barium-water-sprayed plat, 168 pounds, 5 per cent rot; check plat, 130 pounds, 6 per cent rot. The barium-water-sprayed plat adjoined a check plat, while the Bordeaux-sprayed plat had sprayed plats on either side.

BARIUM-WATER SPRAYS IN 1918.

In 1918 a barium-water spray containing 0.7 per cent of copper sulphate, which had given excellent results in 1917, was tested on acre plats in a commercial way, and another barium-water spray, containing 0.6 per cent of copper sulphate, was tested on a smaller scale.

The plats to which 0.7 per cent barium-water spray was applied on the commercial scale gave blight yield readings of from 1 to 2.3 per cent as compared with readings of from 1.2 to 2.0 per cent in the

case of those sprayed with standard Bordeaux and of from 20 to 50 per cent in the case of the unsprayed plats. The barium-water-sprayed plats yielded from 264 to 303 pounds of tubers, the Bordeaux-sprayed plats from 247 to 313 pounds, and the check plats 215 pounds.

The application of the 0.6 per cent barium-sulphate spray to smaller plats gave an average blight reading of 1.7 per cent, as compared with 0.5 and 1.2 per cent for the Bordeaux, 5-5-50, mixture, and 33 and 45 per cent when no spray was used. The yields of tubers from two rows, each 150 feet long, were: Bordeaux-sprayed plat, 244 pounds; check plat, 235 pounds; barium-water-sprayed plat, 241 pounds.

These results, extending over three seasons, particularly those of 1917 and 1918, indicate that a spray made with barium hydrate and containing 0.7 per cent of copper sulphate gives a satisfactory control of blight and the same yield of tubers as a Bordeaux, 5-5-50, containing 1.25 per cent of copper sulphate. Plate II, figure 2, shows the protective action given by the barium-water spray in 1918, when the blight was severe.

In preparing the barium-water spray containing 0.7 per cent of copper sulphate, equal parts of copper sulphate and barium hydrate (2.8 pounds of barium hydrate and 2.8 pounds of copper sulphate to 50 gallons) were found to be satisfactory. While such a spray gave good results and reduced the copper sulphate used 44 per cent, the price of barium hydrate is so high that such a spray can not be considered commercially practicable at the present time. If the price of barium hydrate drops, or if barium chlorid, which sells for \$75 per ton, can be used, an effective spray may be cheaply prepared. The fact that no residue is left, that the barium hydrate may be added to the spray tank with the water and dissolved there, and that there is reduced wear and tear on apparatus, may induce a trial of this spray, particularly if the yields are shown to be stimulated to a greater extent than with Bordeaux, 5-5-50.

REDUCED MILK-OF-LIME SPRAYS IN 1917.

Bordeaux, 3-3-50 and 3-1½-50, sprays were applied to potatoes during the season of 1917. The reason for reducing the proportion of lime used as milk of lime was to determine its influence on the fungicidal power of the copper and its effect upon the adhesive properties of the spray.

Blight control.—Check plat, 71 per cent; plat sprayed with Bordeaux, 5-5-50, 13 per cent; plat sprayed with Bordeaux, 3-3-50, 38 per cent; and plat sprayed with Bordeaux, 3-1½-50, 26 per cent.

Yield.—Check plat, 139 pounds; plat sprayed with Bordeaux, 5-5-50, 158 pounds; plat sprayed with Bordeaux, 3-3-50, 148 pounds; plat sprayed with Bordeaux, 3-1½-50, 172 pounds.

Rotten tubers.—Check plat, 3 per cent; plat sprayed with Bordeaux, 5-5-50, 4 per cent; plat sprayed with Bordeaux, 3-3-50, 8 per cent; plat sprayed with Bordeaux, 3-1½-50, 8 per cent.

The Bordeaux, 5-5-50, spray gave the lowest average readings for blight. The largest yield of tubers came from the plat sprayed with Bordeaux, 3-1½-50. Apparently the percentage of rotten tubers was not influenced by the spray used. The fact that the plats sprayed with Bordeaux, 3-3-50 and 3-1½-50, were on lower ground than the other two plats, together with the wetness of the season, accounted for the high percentage of rotten tubers found on them.

REDUCED MILK-OF-LIME SPRAYS IN 1918.

In 1918 one-acre plats were sprayed with Bordeaux, 4-4-50, 4-2-50, and 4-1-50, to determine the influence of varying amounts of lime on a definite amount of copper. The average results of these tests, which were conducted on the same fields as the Pickering and barium-water tests, appear in Table 3.

The blight readings are so low that it is impossible to draw a definite conclusion from them. Those for the plats sprayed with Bordeaux, 5-5-50 and 4-4-50, are lower than those for the plats sprayed with Bordeaux, 4-2-50 and 4-1-50. While the Bordeaux, 4-1-50, gave somewhat larger yields than the other sprays, the average yields of tubers were practically the same for all the sprayed plats. The slight variation which exists is undoubtedly due to the location of the plats and the fertilizer used rather than to the sprays.

ADHERENCE OF COPPER FROM SPRAYS TO LEAVES.

The power of various sprays to adhere to potato leaves was tested by Girard (11), who employed standard Bordeaux, Bordeaux made with half the usual amount of lime, Bordeaux made with aluminum sulphate, copper and soda mixture, and copper and acetate of lime mixture. The sprayed plats were subjected to artificial rain for various periods. The Bordeaux spray made with half the usual amount of lime left the largest amount of copper on the leaves. The addition of sulphate of aluminum was of no value. Butler (7) also concludes that a Bordeaux mixture made with a medium amount of lime has greater adhesive properties than one to which the full amount of lime has been added, and considers the alkaline Bordeaux sprays more adhesive than the acid or neutral Bordeaux sprays.

Method of estimating copper on leaves.—To determine how much of the copper from the various sprays actually remained on the potato leaves, sets of 50 leaves were picked from the vines on the different plats, the leaves from each plat being placed in separate envelopes. Directly after picking tracings were made of the outlines of the leaves and were later measured with a planimeter to obtain the areas of

the leaves. The area of one side of the leaves only was used in making the calculations. The leaves were dried and used for analysis for copper. The results were expressed as milligrams of copper per square millimeter of leaf surface. By weighing the leaves when dry it was then possible to express the results both as parts of copper per million on the dried leaves and as milligrams of copper per square meter of leaf surface.

Method of determining copper on leaves.—The leaves were placed in 4½-inch porcelain dishes and ashed in the muffle at dull red heat. The ash was covered with 30 cc. of 1-3 nitric acid and allowed to stand over night. It was then filtered and washed, the filtrate made faintly ammoniacal, and brought to a boil. Next it was cooled, made to suitable volume, and filtered. An adequate aliquot was taken for the colorimetric estimation of the copper. This aliquot, as well as solutions of standard copper sulphate, containing added ammonia and nitric acid, were evaporated to dryness in clean, white, 3-inch porcelain dishes. To the residues 5 cc. of distilled water and 3 drops of acetic acid were added, and finally 3 drops of 10 per cent potassium ferrocyanid, the dishes being rotated to mix the solutions, which were immediately compared with the standards. The results are expressed as parts of copper per million. This method has been checked against the electrolytic copper method and found to give good results. The standard copper sulphate solution was made to contain 0.0001 gram of copper per cc.

IN 1916.

On August 12, two days after the third spray had been applied, a set of leaves (lot 1) was taken from the vines on the sprayed plats. On August 24, seven days after the leaves had been sprayed, additional samples of leaves (lot 2) were taken. The results of the analyses, which were made in duplicate, are given in Table 5. Average results for four sets of leaves, or 200 leaves, from each plat show that the barium-water and three of the seven Pickering sprays employed left a higher percentage of copper on the leaves to 0.1 per cent of copper sulphate present in the spray than Bordeaux, 5-5-50. The other four Pickering sprays did not show as high a ratio of copper on the leaves as did the Bordeaux, 5-5-50. It must be remembered, of course, that the Pickering sprays were applied four times, while the Bordeaux spray was applied five times. Although the Bordeaux-sprayed leaves always showed the presence of more copper than any of the others, it is apparent that, considering the amount of copper sulphate used, the copper of the Pickering sprays adhered equally as well. The leaves from the vines treated with Pickering (A) spray and rosin-fish-oil soap showed the presence of more copper than did those from the vines sprayed with plain Pickering (A) spray containing 0.38 per cent of copper sulphate. The amounts of copper on the leaves of the vines

sprayed with Pickering (A) and (C) sprays varied markedly. On an average more copper was found on the leaves sprayed with Pickering (C) sprays than on those treated with Pickering (A) sprays.

TABLE 5.—Adherence of copper from various sprays to potato leaves (northern Maine).

Plat No.	Spray.	Copper sulphate in spray.	Copper adhering to leaves.							
			Parts per million (dry basis).		Parts per million per 0.1 per cent CuSO_4 in spray (dry basis).		Mg. per square meter of leaf surface.		Mg. per square meter of leaf surface per 0.1 per cent CuSO_4 in spray.	
			Lot 1. ¹	Lot 2. ²	Lot 1. ¹	Lot 2. ²	Lot 1. ¹	Lot 2. ²	Lot 1. ¹	Lot 2. ²
1916.		<i>Per cent.</i>								
.....	Standard Bordeaux, 5-5-50.....	1.25	163.3	332.6	13.0	26.6	31.15	.....	2.5	.....
.....	Pickering (A).....	.64	149.7	53.7	23.4	8.4	15.77	.....	2.4	.....
.....	do.....	.38	29.4	22.3	7.7	5.9	8.00	.....	2.1	.....
.....	do.....	.13	35.8	19.6	27.6	15.1	11.64	.....	9.0	.....
.....	do.....	.065	9.11	7.2	14.0	11.1	8.80	.....	1.2	.....
.....	Pickering (C).....	.23	42.9	23.8	18.7	10.3	7.97	.....	3.5	.....
.....	do.....	.115	36.6	18.9	31.8	16.4	5.99	.....	5.2	.....
.....	do.....	.36	61.8	97.9	17.2	27.2	12.80	.....	3.6	.....
.....	Pickering (A) and rosin-fish-oil soap.....	.38	120.8	54.0	31.8	14.0	24.13	.....	6.4	.....
.....	Barium water.....	.38	73.6	38.0	19.4	10.0	5.98	.....	1.6	.....
1917.										
1.....	Pickering (A).....	.7	519.8	571.7	74.2	81.7	11.17	18.61	1.60	2.66
2.....	do.....	.6	455.1	533.9	75.8	89.0	10.64	13.07	1.77	2.18
3.....	Pickering (C).....	.6	422.6	373.6	70.4	62.3	10.96	10.39	1.83	1.73
4.....	Pickering (A).....	.5	338.1	431.5	69.6	86.3	6.98	14.13	1.40	1.83
5.....	do.....	.5	277.5	334.5	55.5	66.9	5.34	8.96	1.07	1.80
6.....	do.....	.4	274.2	319.3	68.6	79.8	6.25	9.10	1.56	1.82
7.....	Pickering (C).....	.4	111.9	200.5	28.0	50.1	2.11	7.00	.53	1.78
8.....	do.....	.3	138.6	163.3	46.2	54.4	3.32	3.97	1.11	1.32
12.....	Pickering (A) and rosin-fish-oil soap.....	.5	141.4	338.0	28.3	67.6	2.96	9.24	.59	1.85
13.....	Pickering (A) and lead arsenate.....	.5	128.9	275.0	25.8	55.0	2.66	8.57	.53	1.71
14.....	Pickering (C) and lead arsenate.....	.5	213.3	390.0	42.7	78.0	4.38	10.02	.88	2.00
.....	Bordeaux, 5-5-50.....	1.25	387.4	1,073.7	31.0	86.0	7.55	30.00	.66	2.40
Check.	.....			41.8						
Check.	.....			22.05						
.....	Bordeaux, 3-3-50.....	.75	363.0	956.19	48.4	127.5	5.87	31.71	.78	4.23
.....	Bordeaux, 5-5-50.....	1.25	566.4	1,641.60	45.3	131.3	22.12	48.74	1.77	3.90
.....	Bordeaux, 3-1½-50.....	.75	618.1	1,098.0	82.4	146.4	11.41	31.44	1.52	4.19
Check.	.....			16.9						
.....	Barium water.....	.7	271.4	878.3	38.8	125.5	5.86	21.37	.84	3.05
.....	Burgundy mixture.....	1.25		1,217.5		97.4		36.19		2.89
.....	Bordeaux, 5-5-50.....	1.25		1,703.0		136.4		51.57		4.13
1918.										
1.....	Pickering (A).....	.7	1,650	1,700	236	243	.....	.....	.....	.....
2.....	Barium water.....	.7	1,400	1,100	200	157	.....	.....	.....	.....
3.....	Bordeaux, 4-4-50.....	1.0	1,950	1,700	195	170	.....	.....	.....	.....
4.....	Bordeaux, 4-2-50.....	1.0	1,850	1,500	185	120	.....	.....	.....	.....
5.....	Bordeaux, 4-1-50.....	1.0	1,400	1,200	140	184	.....	.....	.....	.....
6.....	Bordeaux, 5-5-50.....	1.25	2,250	2,300	180	.....	.....	.....	.....	.....
A.....	Pickering (A).....	.6	1,300	.....	217	.....	.....	.....	.....	.....
C.....	Pickering (C).....	.6	1,400	.....	233	.....	.....	.....	.....	.....
D.....	Bordeaux.....	.6	1,400	.....	233	.....	.....	.....	.....	.....
E.....	Barium water.....	.6	1,200	.....	200	.....	.....	.....	.....	.....
F.....	Copper sulphate and lead arsenate.....	.6	900	.....	150	.....	.....	.....	.....	.....

¹ In 1916, picked two days after spraying, and in 1917, eight days after spraying.

² In 1916, picked seven days after spraying, and in 1917, two days after spraying.

IN 1917.

Leaves picked on August 11, eight days after spraying (lot 1) and on August 24, two days after spraying (lot 2), were analyzed with the results shown in Table 5.

Lot 1.—The copper of the Pickering sprays adhered to the leaves in proportionally greater amounts than that of the Bordeaux spray. Per unit of copper sulphate in the spray more copper was deposited on the leaves sprayed with the three Pickering sprays which contained the highest percentages of copper sulphate than on those sprayed with Bordeaux, but less on the leaves treated with the other Pickering sprays. The results for copper on the leaves sprayed with barium water were low. Of the leaves treated with the 3-3-50 and 3-1½-50 sprays those receiving the 3-1½-50 spray showed the largest deposits.

Lot 2.—As a rule, more copper adhered to the leaves sprayed with Bordeaux than to those to which any of the other sprays were applied. In several instances, however, the results for the Pickering-sprayed leaves were equal to those for the Bordeaux-sprayed leaves per unit of copper sulphate in the spray. The addition of lead arsenate or rosin-fish-oil soap to the Pickering sprays did not increase the amount of copper which adhered to the leaves. More copper adhered to the leaves sprayed with standard Bordeaux than to those sprayed with barium water or Burgundy mixture.

Average results.—More of the copper of the Pickering (A) than of the Pickering (C) sprays adhered to the leaves. In three of the eight Pickering sprays tested, the copper adhered to the leaves in a higher proportion per copper sulphate content of the spray than the copper of the standard Bordeaux, 5-5-50. The Bordeaux, 3-1½-50, spray gave higher results than either the Burgundy mixture or barium water. In proportion to the amount of copper sulphate present in the spray, the Burgundy mixture gave the lowest results of all.

IN 1918.

During the season of 1918, the adherence of copper to potato leaves was determined for Pickering (A) spray, containing 0.7 per cent of copper sulphate, for barium-water spray, with the same copper sulphate content, and for Bordeaux, 4-4-50, 4-2-50, and 4-1-50, sprays, each containing 1 per cent of copper sulphate. The results (Table 5) are very uniform except those for the Bordeaux, 4-1-50, spray, used on plat 5, which gave lower figures than the sprays used on plats 1, 2, 3, 4, and 6. The highest average figure for copper per unit of copper sulphate in the spray was obtained in the case of the Pickering (A) spray with a copper sulphate content of 0.7 per cent, applied to plat 1. In the tests on plats A, C, D, E, and F, in which sprays containing 0.6 per cent of copper sulphate were employed, the amount of copper adhering on the leaves treated with Pickering (C) spray was the same as the amount adhering to those sprayed with Bordeaux. The leaves sprayed with Pickering (A) spray gave slightly lower results and those treated with the barium-water spray,

still lower ones. The solution of copper sulphate and lead arsenate did not seem to adhere to the leaves as well as the other sprays.

SUMMARY.

The various Pickering and Bordeaux sprays tested adhered equally well to the potato leaves. Little difference was noted between the adhesive property of the copper from the Pickering (A) and that of the copper from the Pickering (C) solutions. The 1916 results favored the Pickering (C) spray, while the 1917 results were higher in the case of Pickering (A) sprays. The addition of either rosin-fish-oil soap or lead arsenate to a Pickering spray failed to increase its adhesive properties. In 1916 the results on leaves sprayed with barium-water spray were higher than, in 1917 lower than, and in 1918 equal to the standard Bordeaux results. A reduction in the amount of milk of lime used in preparing a standard Bordeaux type of spray did not appear to influence the adhesive properties of the spray until the amount used was less than that necessary to combine with the copper present, when a decrease in adhesive power resulted. The copper of the Burgundy mixture (sal-soda Bordeaux) did not adhere as well as the copper of standard Bordeaux, for the reason that all of the copper had not been precipitated by the sal soda.

INJURY TO VINES AND TUBERS.

No injury to vines or tubers was observed as the result of the application of any of the sprays used in these tests.

SUMMARY.

PICKERING SPRAYS.

A Pickering spray containing 0.7 per cent of copper sulphate controlled the late blight as well as, and gave yield results equal to those obtained with, Bordeaux, 5-5-50, containing 1.25 per cent of copper sulphate. The copper in the Pickering sprays was apparently twice as effective as that in standard Bordeaux, 5-5-50. Pickering sprays containing 0.6 per cent of copper sulphate gave the same yield of tubers and nearly as effective control of late blight as Bordeaux, 5-5-50. Pickering sprays containing less than 0.6 per cent of copper sulphate did not give satisfactory control of late blight. The claims of Bedford and Pickering (3, 4) that the copper of the limewater sprays is from 10 to 12 times as effective as the copper of standard Bordeaux were not substantiated by the results of these experiments. Pickering (A) and (C) sprays were found to be equally effective in controlling late blight on potatoes.

The Pickering sprays adhered to the leaves as well as standard Bordeaux. The use of rosin-fish-oil soap or lead arsenate with Pick-

ering sprays did not materially influence their adhesive properties on potato leaves. No injury to the leaves or to the potato plants was caused by any of the Pickering sprays tested.

The amount of copper sulphate essential for the control of late blight on potatoes in Maine may be reduced 44 per cent by the use of Pickering sprays. The amount of lime required is reduced also and all grit removed from the spray, while at the same time the wear and tear on spray machinery is greatly diminished. These results were obtained in Maine where the principal potato trouble is late blight. It is impossible to state what the efficacy of Pickering sprays on potatoes would be in sections where other troubles predominate.

BARIUM-WATER SPRAYS.

Tests with a barium-water spray containing 0.7 per cent of copper sulphate showed that it gave practically the same control of late blight and the same yields as Bordeaux, 5-5-50. In fact, in 1917 and 1918 the yields were slightly larger on plats sprayed with barium water than on those sprayed with Bordeaux.

REDUCED-MILK-OF-LIME SPRAYS.

The 3-1½-50 spray tried in 1917 (a severe blight year) gave a larger yield and a lower blight reading than the 3-3-50 spray. In 1918, the blight readings for the plats where the 4-1-50 spray was employed were a little higher than for those where the 4-4-50 spray was used. Apparently the amount of lime present in a Bordeaux spray used for potatoes in Maine has little effect on the fungicidal power. As long as sufficient lime is present to combine with the copper, the extra lime has no fungicidal advantage, but has several disadvantages.

Less copper adhered to the leaves when a 4-1-50 spray was employed than when 4-4-50 and 4-2-50 sprays were used. This may be explained by the presence of free copper sulphate in the 4-1-50 sprays.

STANDARD BORDEAUX SPRAYS.

In sections where the blight may be severe, such as northern Maine, a Bordeaux, 5-5-50, is recommended. In other States where the blight is usually less severe a Bordeaux, 4-4-50, is desirable.

GRAPES.

CONTROL OF FUNGOUS DISEASES.

IN NEW JERSEY.

Four acres of Concord grapes near Vineland, N. J., were treated with Pickering (A) and (C) sprays, varying in copper sulphate content from 0.065 to 0.64 per cent, and with a standard Bordeaux,

3-3-50, spray, containing 0.75 per cent of copper sulphate. A Pickering (A) spray containing 0.38 per cent of copper sulphate was used alone and in combination with rosin-fish-oil soap. One plat was held unsprayed as a check plat. The sprays were applied on May 18, May 27, June 15, and July 7, 1916. A power sprayer was used for each spraying with the Bordeaux and for the May sprayings with the Pickering spray, while a hand-pump sprayer was employed for the June and July applications of the Pickering spray. Because of injury to the vines sprayed with the strongest Pickering solutions after a severe hail storm occurring on June 11, no further applications of these sprays were made. The spraying of one or two rows of grapes with the weaker Pickering sprays was, however, continued throughout the season.

TABLE 6.—*Effect of various sprays on blight and yield of grapes (New Jersey).*

Plat No.	Spray used.	Copper sulphate in spray.	Condition of fruit when picked.				Net weight of grapes picked from two rows.	Spray injury noted June 13.
			Sound.	Black rot.	Downy mildew.	Total diseased.		
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Lbs.</i>	
1.....	Pickering (A).....	0.64	(1)	(1)	(1)	(1)	121	Leaves and fruit greatly injured; many buds destroyed.
2.....	do.....	.38	(1)	(1)	(1)	(1)	411	Almost complete defoliation; part of fruit destroyed.
2.....	Pickering (A) and rosin-fish-oil soap.	.38	(1)	(1)	(1)	(1)	784	Do.
3.....	Pickering (A) ²	.13	76.12	21.17	2.71	23.88	.....	Leaves noticeably injured.
3.....	do. ²	.13	71.68	25.00	3.33	28.33	961	Do.
4.....	do.....	.965	69.63	25.98	4.39	30.37	1,501	Leaves slightly injured.
5.....	Pickering (C) ²	.23	(1)	(1)	(1)	(1)	.....	Large proportion of leaves destroyed.
5.....	do. ²	.23	(1)	(1)	(1)	(1)	949	Do.
6.....	do.....	.115	85.09	12.43	1.48	14.01	1,502	Leaves slightly injured.
7.....	do.....	.36	(1)	(1)	(1)	(1)	892	Large proportion of leaves destroyed.
.....	Bordeaux, 3-3-50.....	.75	92.91	6.79	.29	7.02	1,375	Leaves slightly injured.
Check.....	.....	.....	.00	70.64	37.53	100.00	830	.....

¹ Fungus control satisfactory.² Spray applied three times.³ Spray applied to first two rows four times.

The results for the control of fungus diseases in New Jersey (Table 6) indicate that the control of disease was in direct proportion to the spray injury of the vines. Apparently the strongest Pickering spray, which contained 0.64 per cent of copper sulphate (plat 1), controlled the fungus diseases more effectively than the Bordeaux sprays, showing the high availability of the copper of the Pickering sprays. The injury, however, was so severe that the spray could not be used commercially.

IN VIRGINIA.

Two acres of grapes, largely Concord, in poor condition, in Vienna, Va., were sprayed with Pickering sprays and with a standard Bor-

deaux, 3-3-50, spray. The Pickering spray was used alone and in combination with rosin-fish-oil soap. The sprays were applied four times, May 15-16, May 25-26, June 12-13, and July 1-3, 1916, with a barrel pump sprayer.

Early in July many spots of black rot were seen on the leaves of the check plat, but none on the leaves of the sprayed plats. On June 26 some black-rot spots were observed on the leaves from all plats except those sprayed with Bordeaux, 3-3-50, and Pickering (A) containing 0.64 per cent of copper sulphate (plats A and 1). Plat 7, sprayed with Pickering (C) containing 0.36 per cent of copper sulphate, showed very few spots. The check plat showed the largest number of infected leaves. One row of vines in plat 1 did not receive the second application. These vines showed neither the spray injury nor the control of rot apparent in the rest of the vines of plat 1.

TABLE 7.—*Effect of various sprays on black rot of grape leaves (Virginia).*

Plat No.	Spray used.	Copper sulphate in spray.	Amount of black-rot leaf spot.	Remarks.
		<i>Per cent.</i>	<i>Per cent.</i>	
A.....	Bordeaux, 3-3-50.....	0.75	3.5	Condition of vines good; slightly injured.
1.....	Pickering (A).....	.64	3.5	Leaves and fruit badly injured.
2.....	do.....	.38	5.0	Leaves severely injured; fruit somewhat.
2b.....	Pickering (A) and rosin-fish-oil soap.	.38	5.0	Do.
3.....	Pickering (A).....	.13	11.0	Slight burning of leaves.
5.....	Pickering (C).....	.23	6.5	Do.
7.....	do.....	.36	5.0	Leaves severely injured; fruit somewhat.
Check.....	.....	.00	100.0	Vines not much injured.

The results in Table 7 show that the four strongest Pickering sprays tested (plats 1, 2, 2b, and 7) and the standard Bordeaux spray gave an excellent control of black-rot leaf spot on the leaves. The sprays used on plats 3 and 5 gave a less effective control of the disease. Black-rot spots were seen on the leaves of all the vines on the check plat. The weeds in the vineyard were high, and the weather was moist, rendering conditions for infection excellent. Of all the experimental plats, No. 5 looked the best, although not as well as the plat sprayed with standard Bordeaux.

YIELD.

IN NEW JERSEY.

The yield of grapes sprayed varied with the injury to the vines, which in turn depended upon the percentage of copper sulphate in the Pickering sprays employed. The two weakest (those used on plats 4 and 6) gave good yield results, but plat 4 showed only 69 and plat 6 only 85 per cent of sound berries, as compared with 93 per cent obtained from the plat sprayed with Bordeaux, 3-3-50.

IN VIRGINIA.

It was considered impracticable to attempt to determine the weight of grapes from the different plats in Virginia. From the three rows sprayed with Bordeaux 26 crates of grapes were obtained, an average of $8\frac{3}{4}$ crates per row. From the 20 rows of grapevines sprayed with the Pickering sprays 26 crates of salable grapes were secured, an average of 1.3 crates per row. No grapes were harvested from the unsprayed check rows. Not all of the grapes from the plats sprayed with Pickering spray were picked, as some of the fruit was small and immature.

ADHERENCE OF COPPER FROM VARIOUS SPRAYS TO LEAVES.

IN NEW JERSEY.

Duplicate samples of leaves from the plats treated with the various sprays were gathered on June 6 (10 days after the second spraying) and on June 8 (12 days after the second spraying). Forty leaves from each set were analyzed, the results obtained on those gathered on June 6 being shown in Table 8. The area of one side only of the leaves was considered in calculating the area figures. The outlines of the fresh leaves were traced on paper, and the tracings later measured by a polar planimeter (p. 17).

TABLE 8.—*Adherence of copper from various sprays to grape leaves.*

Plat No.	Spray used.	Copper sulphate in spray used.	Copper adhering to leaves.			
			Parts per million (dry basis).	Parts, per million, per 0.1 per cent CuSO_4 in spray.	Mg. per square meter of leaf surface.	Mg. per square meter of leaf surface per 0.1 per cent CuSO_4 in spray.
New Jersey:		<i>Per cent.</i>				
B.....	Bordeaux, 3-3-50.....	0.75	1,459	194	64.0	8.5
1.....	Pickering (A).....	.64	982	153	46.2	7.2
2.....	do.....	.38	750	197	29.9	7.8
2a.....	Pickering (A) and rosin-fish-oil soap.....	.38	709	187	27.8	7.3
3.....	Pickering (A).....	.13	383	295	14.1	10.8
4.....	do.....	.065	110	170	.4	.6
5.....	Pickering (C).....	.23	110	48	4.2	1.8
6.....	do.....	.115	184	160	6.2	5.4
7.....	do.....	.36	285	80	10.5	3.0
Check.....			11		.4	
Virginia:						
A.....	Bordeaux, 3-3-50.....	0.75	1,440	192	44.6	6.0
1.....	Pickering (A).....	.64	191	30	6.9	1.1
2.....	do.....	.38	18	5	.7	.2
2b.....	Pickering (A) and rosin-fish-oil soap.....	.38	392	103	16.1	4.2
3.....	Pickering (A).....	.13	(¹)			
5.....	Pickering (C).....	.23	174	76	5.6	2.4
7.....	do.....	.36	321	89	12.8	3.6
Check.....						

¹ Trace.

The area results show more decisively than do the weight results that the copper from the Pickering (A) sprays adhered to the leaves in proportionately greater amounts than did that from the Pickering

(C) sprays. The leaves sprayed with Bordeaux mixture contained more copper and a higher ratio of copper per unit of copper sulphate present in the spray than the average for those treated with the Pickering sprays, showing that the copper of the Pickering sprays did not adhere to the grape leaves as well as that of the standard Bordeaux spray. The addition of rosin-fish-oil soap to the Pickering (A) spray used on plat 2 did not increase the adherence of copper to the leaves.

IN VIRGINIA.

Duplicate sets of leaves from the plats treated with the different sprays were gathered on June 1 (six days after the second spraying) and on June 3 (eight days after the second spraying) and analyzed (Table 8).

The results, both by weight and area, for the leaves gathered June 1 show that the copper of the Bordeaux spray adhered practically twice as well as that from the Pickering sprays. The use of rosin-fish-oil soap seemed to be of decided advantage. These results do not agree with those obtained by analyzing leaves in New Jersey where similar sprays were used. The low results for copper on the Pickering-sprayed leaves in Virginia, as compared with those obtained on leaves treated with sprays of the same formula and strength in New Jersey, may be accounted for in part by the fact that in New Jersey the first two applications were made with a power sprayer.

INJURY TO VINES.

IN NEW JERSEY.

Until the severe hail storm of June 11 no burning or other injury was noticed on the Pickering-sprayed plats. After the storm, however, the leaves were torn, the grapes were punctured, and young shoots broken from the vines. The Pickering-sprayed plats were then reduced in size, only one or two rows of the vines treated with the weaker Pickering sprays being continued through the rest of the season. The stronger Pickering sprays were dropped entirely. By July 7 new foliage had appeared on all the vines and no additional injury was evident.

Copper sprays used on grapes are often mixed with lead arsenate. Lead arsenate, however, was not used with the Pickering or Bordeaux sprays in this investigation. Consequently its influence on the burning of the foliage was not determined.

The Pickering sprays containing 0.23 per cent and more of copper sulphate controlled the fungous diseases as well as the Bordeaux spray. As commercial sprays, however, they are impracticable because of their tendency to injure the grape leaves and fruit. The use of rosin-fish-oil soap with Pickering (A) containing 0.38 per cent of copper did not affect the caustic properties of the spray.

IN VIRGINIA.

On June 10 a heavy hail storm broke the leaves, punctured the grapes, and broke off many shoots from the vines. Two or three days after the storm serious burning of the leaves was noticed. This injury was particularly severe on the plats sprayed with the strongest Pickering solutions. The weakest Pickering spray produced about the same injury as the Bordeaux spray. On June 26 new growth appeared on all the sprayed vines, and a fourth spraying was made on July 3, with no additional spray injury. As in the case of the tests in New Jersey, the injury to the leaves was in direct proportion to the percentage of copper sulphate present in the Pickering sprays.

Among the numerous theories advanced to explain the burning or scorching of foliage by copper sprays are the following: (1) A specific susceptibility of the protoplasm of the plant to copper; (2) solvent properties or activities of the cell sap of the plant on the copper compound of the spray; (3) permeability of the epidermis or cuticle to the cell contents when conditions are favorable for exosmosis and for a trace of copper which has been rendered soluble; (4) weather conditions following spraying, particularly moisture, which provides suitable conditions for the exosmosis of some of the contents of the cells of leaves; (5) the amount of spray on the leaves or foliage, the proportions of other constituents, such as lime, to the copper in the spray, the condition of the leaves, whether normal or injured by the weather, insects, etc., and, above all, the climate.

EFFECT ON MATURING OF FRUIT.

IN VIRGINIA.

At the time of picking, samples of grapes from the different plats were analyzed for reducing sugar, sucrose, and acidity, using the methods of the Association of Official Agricultural Chemists, in order to determine the influence of the sprays in preventing a proper maturing of the fruit.

TABLE 9.—*Effect of various sprays on composition of grapes (Virginia).*

Plat. No.	Spray used.	Copper sulphate in spray used.	Composition of grapes at picking time.		
			Reducing sugar.	Sucrose.	Acidity.
		Per cent.	Per cent.	Per cent.	Cc. normal alkali per kilo.
A.....	Bordeaux, 3-3-50.....	0.75	7.35	0.07	162
1.....	Pickering (A).....	.64	10.52	.22	152
2.....	do.....	.38	8.57	.42	159
2b.....	Pickering (A) and rosin-fish-oil soap.....	.38	8.54	.10	157
3.....	Pickering (A).....	.13	7.50	.10	155
5.....	Pickering (C).....	.23	9.10	.28	152
7.....	do.....	.36	7.60	.20	151

The results (Table 9) naturally varied with the condition of the individual samples. The grapes from plat A, sprayed with standard Bordeaux mixture, showed the highest acidity and the lowest sugar content, while those from plat 1, treated with Pickering spray containing 0.64 per cent of copper sulphate, gave the highest content of sugar and a low acidity. Since the percentage of sugar increases and the percentage of acidity decreases during the ripening of grapes, no influence of the sprays in preventing a proper maturing of the fruit is indicated. On the contrary, an increase in the sugar content and a decrease of acid is evident in the Pickering-sprayed grapes, compared with those sprayed with Bordeaux. As no unsprayed grapes were analyzed, it is impossible to state whether or not the copper in the sprays exerted a stimulating action on the grapes.

The variation in the composition of the grapes sprayed with Pickering and Bordeaux may possibly be due to the greater availability of the copper in the Pickering sprays. The fact that more burning resulted from using the Pickering sprays than from using the Bordeaux sprays is evidence of a greater availability, or at least solubility, of the copper of the Pickering sprays. It has been suggested that the effect of the sprays on the composition of the fruit came through foliage injury.

SUMMARY.

Pickering (A) and (C) sprays, containing 0.64, 0.36, and 0.38 per cent of copper sulphate, caused severe injury to the grape foliage and fruit after a hail storm which tore the leaves and injured the vines both at Vineland, N. J., and Vienna, Va., in 1916. Under similar conditions the Pickering sprays containing 0.23, 0.13, 0.115, and 0.065 per cent of copper sulphate caused less injury than the stronger Pickering sprays, but more injury than standard Bordeaux, 3-3-50, containing 0.75 per cent of copper sulphate.

The strongest Pickering spray, that employed on plat 1, controlled the black rot fully as well as the Bordeaux, 3-3-50, and the Pickering sprays containing 0.36 and 0.38 per cent of copper sulphate showed practically as effective control as the Bordeaux. The weaker Pickering sprays, containing 0.23 per cent of copper sulphate or less, did not control the black rot as well as the Bordeaux spray.

The yield of grapes was reduced by all of the Pickering sprays except the two weaker ones.

The copper of the Pickering sprays did not adhere to the grape leaves as well as the copper of the Bordeaux, 3-3-50. The averages of all the results obtained, including some not reported in the tables, show that where the Pickering sprays were applied with a power

sprayer as a fine mist (Vineland, N. J.) about one-half as much copper in proportion to that used in the spray adhered to the leaves as when standard Bordeaux was used. When the Pickering sprays were applied with a hand pump (Vienna, Va.), the ratio of copper retained on the leaves was still further reduced in the case of the Pickering sprays.

The use of rosin-fish-oil soap with one of the Pickering sprays proved advantageous in the Virginia tests, but not in the New Jersey tests.

Apparently the copper of the Pickering sprays exists in a more active and available form than the copper of the Bordeaux spray, as evidenced by the severe burning of the grape leaves. No differences were detected in the caustic action or in the adhesive properties of the Pickering (A) and (C) sprays. The caustic action and the fungicidal properties of the sprays made by the two formulas were apparently the same.

The Pickering sprays seem to be too caustic for spraying grapes. These sprays, however, may have a very definite use for the last application when this must be made late in the season after the berries are half grown. Bordeaux spray applied late in the season tends to remain on the berries, which is undesirable. Pickering sprays, however, are nonstaining.

APPLES.

CONTROL OF FUNGOUS DISEASES.

An orchard of Yellow Newtown (Albemarle Pippin) trees at Greenwood, Va., where bitter rot is prevalent, was selected for these experiments. The orchard was not well cultivated and was famous as a place for bitter rot.

IN 1916.

Of the 27 trees in the orchard 12 were sprayed with Pickering sprays, 12 with standard Bordeaux, 4-5-50, and three were left unsprayed. The sprays were applied three times, June 23, July 13, and July 27. The Bordeaux spray was applied with a power sprayer each time. The Pickering sprays were applied the first time with a hand-pump sprayer and afterwards with a power sprayer. The results of this work are shown in Table 10.

TABLE 10.—*Effect of various sprays on bitter rot of apples (Virginia).*

Plat No.	Tree No.	Spray used.	Copper sulphate in spray.	Total apples.	Total apples with rot.	Apples with rot.	Dropped apples.	Apples injured by spray.	Defoliation.
1916.			<i>Per cent.</i>			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
3.	1	Pickering (A).....	0.13	2,522	2,495	99			
3.	2	do.....	.13	2,724	2,701	99			
3.	3	do.....	.13	2,543	2,527	99			
4.	1	do.....	.065	2,934	2,918	100			
4.	2	do.....	.065	2,576	2,574	100			
4.	3	do.....	.065	1,852	1,846	100			
5.	1	Pickering (C).....	.23	1,820	1,810	100			
5.	2	do.....	.23	91	86	95			
5.	3	do.....	.23	2,068	2,000	97			
6.	1	do.....	.115	1,312	1,297	99			
6.	2	do.....	.115	1,797	1,794	100			
6.	3	do.....	.115	1,961	1,961	100			
Check.....	1			3,184	3,144	99			
Do.....	2			3,277	3,265	100			
Do.....	3			1,196	1,196	100			
.....	1	Bordeaux, 4-5-50.....	1.00	3,375	2,566	76			
.....	2	do.....	1.00	1,628	1,200	74			
.....	3	do.....	1.00	2,036	1,885	93			
1917.									
A ₁		Pickering (A).....	.50			.6	3.0	96.2	50
A ₂		do.....	.25			.2	5.2		50
A ₃		do.....	.13			.3	3.0	82.3	
B ₁		Pickering (C).....	.50			1.2	6.3		50
B ₂		do.....	.25			4.1	10.0	95.7	50
B ₃		do.....	.13			.9	10.0		60
.....		Bordeaux, 2-2-50.....	.50			.3	12.7	93.6	30
.....		Bordeaux, 2-1-50.....	.50			.2	9.3		
Check.....		Bordeaux, 4-4-50.....	1.0			.5	45.5	98.0	18
.....						15.2	35.7		20
.....						.1	12.3	25.0	15
.....						.5	6.0	98.0	20
.....						10.3	10.5		
.....						.6	5.5	55.8	20
1918.									
.....		Pickering (C).....	.58	5,724	200	3.5			
.....		Barium water.....	.60	2,594	50	2.0			
Check.....				3,736	736	17.0			
.....		Bordeaux, 4-4-50.....	1.00	4,552		.0			

Bitter rot was first seen in this orchard on July 10. On July 13, the time of the second spray application, there was a little bitter rot on two of the Bordeaux-sprayed trees and on one check tree. A small unhealthy tree in plat 5 showed the most bitter rot. On July 26, at the time of the third spraying, the following observations were made:

Plat 3.—All trees showed a little bitter rot.

Plat 4.—All trees showed a little bitter rot.

Plat 5.—One tree showed a little bitter rot, and the other two trees a good deal of rot.

Plat 6.—One tree showed rot at the top, while the other two were practically free from rot.

Bordeaux-sprayed plat.—Some trees showed no rot and others quite a little. On an average, the trees did not show as much rot as the check trees.

Check plat.—A good deal of rot was seen, more than on the other trees in the orchard.

As only two barrels of sound apples were obtained from the 27 trees, it is apparent that none of the sprays controlled the bitter rot in 1916. Although the apples from the trees sprayed with Bordeaux did not show as much rot as those from the trees sprayed with Pickering sprays or from the check trees, practically every apple from the 12 Bordeaux-sprayed trees was affected to some extent with bitter rot. The failure of any of the sprays to control the bitter rot may be explained by the fact that the rot was severe that season, as well as by the fact that no spray was applied to the trees after July 27.

IN 1917.

Three trees from each of three plats were treated with Pickering (A) and (C) sprays, containing 0.50, 0.25, and 0.13 per cent of copper sulphate. Bordeaux, 4-4-50, was employed as the standard spray. Two trees were sprayed with Bordeaux, 2-2-50, and two with Bordeaux, 2-1-50, sprays, in order to determine the effect of decreasing the lime on the fungicidal action of the copper. Several unsprayed trees were left as controls. The sprays were applied with a power sprayer four times, June 4, June 22, July 9, and August 2. On August 2, because of injury caused by the sprays, the spray was applied to but one tree of plats A₁, A₂, A₃, B₁, B₂, B₃, and to but one of those sprayed with Bordeaux, 2-1-50. On August 30, counts were made of all dropped fruit. All fruit on the trees was picked between September 14 and 18, and counted for rot and for a late type of Bordeaux injury or russetting which developed between August 30 and September 13. The results are shown in Table 10.

Scarcely any bitter rot was present in the orchard in 1917. Consequently, the results prove very little concerning the relative fungicidal value of the sprays tested. On plat B₃, the tree sprayed with Pickering solution was the only one of the sprayed trees which showed any amount of rot, the other two trees of that plat being practically free from rot.

IN 1918.

Pickering (C) spray and a barium-water spray, similar to the one used on potatoes with excellent results (page 11), were used on Cheese apple trees. Ten gallons of the barium-water spray were prepared by dissolving 8 ounces of barium hydrate in 9 gallons of water and adding 2 quarts of copper sulphate stock solution (1 pound per gallon), diluting to 10 gallons with water, and stirring thoroughly. The Pickering (C) spray was prepared according to the directions given on page 7. A Bordeaux, 4-4-50, spray was the standard spray. Two trees were sprayed with the Pickering spray, two with the barium-water spray, and two with standard Bordeaux, while one tree was left unsprayed. The sprays were applied with a power sprayer on June 14, June 28, July 26, and August 13.

At the time of the third spraying it was noticed that three or four apples on the check tree were infected with bitter rot, whereas the sprayed trees seemed to be entirely free from it. On August 13, the date of the fourth application, one or two apples on the Pickering-sprayed, barium-water-sprayed, and Bordeaux-sprayed trees were infected with bitter rot, while the check tree showed a fairly large amount of rot.

At the time of picking very little bitter rot was found on any of the trees. The Bordeaux spray gave 100 per cent protection from bitter rot. The barium-water spray gave a better control of bitter rot than the Pickering spray. The 1918 results (Table 10) are inconclusive because of the small number of apples infected with bitter rot on the sprayed trees.

ADHERENCE OF COPPER FROM VARIOUS SPRAYS TO LEAVES.

IN 1916.

One set of leaves was gathered from the sprayed and check trees on July 12, 13 days after the second spraying, and a second set on July 13, three hours after the third spray had been applied. The outlines of these leaves were immediately traced on paper, and later measured with a polar planimeter. The area of each set of 50 leaves was calculated, but one side of the leaves being used in the calculation. Later the leaves were dried, and the copper determined in each set (Table 11).

TABLE 11.—Adherence of copper from various sprays to apple leaves (Virginia).

Plat No.	Spray used.	Copper sulphate in spray used.	Time between spraying and gathering of leaves.	Copper adhering to leaves.			
				Parts per million (dry basis).	Parts per million per 0.1 per cent of CuSO_4 in spray.	Mg. per square meter of leaf surface.	Mg. per square meter of leaf surface per 0.1 per cent CuSO_4 in spray.
1916.		<i>Per cent.</i>	<i>Days.</i>				
.....	Bordeaux, 4-5-50.....	1.00	13	425	42.5	26.0	2.6
3.....	Pickering (A).....	.13	13	59	45.4	1.3	1.0
4.....	do.....	.065	13	90	138.5	9.3	14.3
5.....	Pickering (C).....	.23	13	248	107.8	25.6	11.1
6.....	do.....	.115	13	77	67.0	2.2	1.9
.....	Bordeaux, 4-5-50.....	1.00	14	3,150	315.0	266.6	26.7
3.....	Pickering (A).....	.13	14	260	200.0	16.0	12.3
4.....	do.....	.065	14	185	284.6	10.2	15.7
5.....	Pickering (C).....	.23	14	646	280.9	15.9	6.9
6.....	do.....	.115	14	249	216.6	20.3	17.7
Check.....	.....	.....	.....	.....	.....	.....	.....
1917.							
.....	Bordeaux, 4-4-50.....	1.00	15	644	64.4	33.8	3.4
Check.....	.....	.....	15	6.6	.....	1.3	.....
.....	Bordeaux, 2-1-50.....	.5	15	318	63.2	15.5	3.1
.....	Bordeaux, 2-2-50.....	.5	15	255	51.0	12.5	2.5
A ₁	Pickering (A).....	.50	15	206	41.2	10.5	2.1
A ₂	do.....	.25	15	146	58.4	6.5	2.6
A ₃	do.....	.125	15	62	49.6	3.0	2.4

TABLE 11.—Adherence of copper from various sprays to apple leaves (Virginia)—Contd.

Plat No.	Spray used.	Copper sulphate in spray used.	Time between spraying and gathering of leaves.	Copper adhering to leaves.			
				Parts per million (dry basis).	Parts per million per 0.1 per cent of CuSO_4 in spray.	Mg. per square meter of leaf surface.	Mg. per square meter of leaf surface per 0.1 per cent CuSO_4 in spray.
1917.		<i>Per cent.</i>	<i>Days.</i>				
B ₁	Pickering (C).....	0.50	15	362	72.4	16.5	3.3
B ₂	do.....	.25	15	136	54.4	7.5	3.0
B ₃	do.....	.125	15	52	41.6	3.0	2.4
.....	Bordeaux, 4-4-50.....	1.00	25	955.9	95.6	46.8	4.7
Check.....	.....	.....	25	8.2	.....	0.15	.....
.....	Bordeaux, 2-1-50.....	.5	25	374.8	75.0	21.1	4.2
.....	Bordeaux, 2-2-50.....	.5	25	595.2	119.0	32.3	6.5
A ₁	Pickering (A).....	.50	25	800.9	160.2	37.4	7.5
A ₂	do.....	.25	25	445.8	178.0	22.2	8.9
A ₃	do.....	.125	25	126.0	101.0	5.6	4.5
B ₁	Pickering (C).....	.50	25	683.3	136.7	33.6	6.7
B ₂	do.....	.25	25	390.0	156.0	19.3	7.7
B ₃	do.....	.125	25	172.3	138.0	9.4	7.5
1918.							
A.....	Pickering (C).....	.58	0	2,250	390	.....	.....
B.....	Barium water.....	.60	0	3,250	542	.....	.....
C.....	Bordeaux, 4-4-50.....	1.00	0	4,350	435	.....	.....
Check.....	.....	.....	0	6	.....	.....	.....
A.....	Pickering (C).....	.58	28	1,450	250	.....	.....
B.....	Barium water.....	.60	28	2,400	400	.....	.....
C.....	Bordeaux, 4-4-50.....	1.00	28	4,150	415	.....	.....
Check.....	.....	.....	28	20	.....	.....	.....

The figures for the copper found on the leaves picked July 26 (13 days after spraying) show that the leaves sprayed with standard Bordeaux held the most actual copper. Calculated per 0.1 per cent of copper sulphate present in the sprays used, however, the leaves sprayed with the Pickering sprays held twice as much copper when calculated by weight and three times as much when calculated by area as did the leaves sprayed with Bordeaux. The figures for the copper found on the leaves picked on July 27 (three hours after the third spraying) are highest in the case of Bordeaux-sprayed trees. The results are much higher for the Bordeaux- than for the Pickering-sprayed leaves when expressed by area and slightly higher when expressed by weight. Evidently, in proportion to the copper sulphate content, the Bordeaux sprays adhered better to the leaves directly after application, although the copper of the Pickering sprays adhered to the leaves in a higher ratio than Bordeaux for the 13-day period tested.

IN 1917.

Two sets of 50 leaves were collected in duplicate from the trees receiving the different sprays, the first on July 7, two weeks after the second spraying, and the second on August 3, nearly four weeks after spraying. The leaves were analyzed for copper, the results of which appear in Table 11.

Of the leaves picked two weeks after spraying, those receiving the Bordeaux, 4-4-50, held the most copper. The leaves sprayed with Bordeaux, 2-1-50, held more copper than those on which 2-2-50 spray was used. No important differences were noted between the adhesive properties of the copper of the Pickering (A) and (C) sprays. In three cases the leaves treated with the Pickering sprays held practically the same amount of copper per 0.1 per cent of copper sulphate used as the leaves sprayed with Bordeaux, 4-4-50. The other three Pickering sprays gave lower results. The results for copper on the leaves by area were slightly in favor of the Bordeaux spray.

The analyses of the second set of leaves, gathered nearly four weeks after spraying, showed the most copper on the Bordeaux-sprayed leaves, although the leaves from plat A₁ sprayed with Pickering spray held 800 parts of copper per million. Contrary to the results recorded on page 19, the leaves receiving the Bordeaux, 2-1-50, spray did not hold as much copper as those sprayed with the Bordeaux, 2-2-50.

All of the Pickering-sprayed leaves held more copper than the Bordeaux-sprayed leaves per unit of copper sulphate in the spray applied, indicating that per unit of copper sulphate present in the spray the copper of the Pickering sprays adheres to apple leaves in larger proportions than the copper of standard Bordeaux spray.

IN 1918.

Leaves from the trees sprayed with Pickering, barium water, and Bordeaux and from the check tree were collected on June 28, just after spraying, and July 26, 1918, 28 days after spraying, and analyzed for copper. The results appear in Table 11.

As the period from the time of the collection of the first set of leaves until the collection of the second set was very dry, about as much copper was found on the second set as on the first set of leaves. The results for the leaves picked immediately after spraying, per 0.1 per cent of copper sulphate present in the sprays, are highest for those receiving the barium-water spray. The Bordeaux-sprayed and the Pickering-sprayed leaves gave practically the same results. The results for the leaves picked 28 days after spraying from Pickering-sprayed trees are low, while those for the barium-water- and the Bordeaux-sprayed leaves are practically identical.

INJURY TO LEAVES AND FRUIT.

IN 1916.

Although the season was wet and sultry, only a trace of injury to the leaves and fruit was noted on the trees treated with Pickering spray. This injury had no practical significance. The Bordeaux spray did not injure the leaves or fruit.

IN 1917.

On June 20 a severe hail storm injured the leaves. On June 21, at the time of the second spray application, some burning of the leaves on the trees treated with the Pickering sprays was noted, as well as a slight burning of the leaves on the trees sprayed with Bordeaux, 4-4-50, 2-2-50, and 2-1-50. The burning caused by the Pickering sprays was far more noticeable than that due to the Bordeaux sprays, and varied among the trees of the same plat. Little difference was evident between the Pickering (A) and (C) sprays with respect to caustic properties on this date. On August 2 the leaves of the trees on plats A₁, A₂, and B₁ showed the most injury. Those sprayed with Bordeaux, 2-1-50, also showed severe burning of the leaves. The trees in the upper portion of the orchard which had been sprayed with standard Bordeaux spray showed marked burning of the leaves, while those sprayed with the standard Bordeaux in the lower part of the orchard showed but slight burning of the leaves.

Part of the Pickering-sprayed trees received only three applications, while the others were sprayed four times. The fourth application of the Pickering sprays produced no additional injury.

All the Pickering sprays reduced the yield of fruit, because of the defoliation occurring during July and August. The fruit on the 18 trees receiving the Pickering sprays was under size. The yield was reduced to a greater extent on the trees sprayed with the Pickering (A) sprays than on those sprayed with the Pickering (C) sprays. Defoliation also caused a reduction in the yields of the Bordeaux-sprayed trees and of those sprayed with Bordeaux, 2-2-50 and 2-1-50. Pickering (C) sprays produced about the same percentage of defoliation as the Bordeaux sprays, while Pickering (A) sprays caused much more defoliation. The figures in Table 10 do not show any influence of the sprays on the percentage of apples that dropped from the trees, which was very high on plats B₂ and B₃. The A series of sprays, which injured the leaves severely and caused the greatest amount of spray injury, showed a low percentage of drops. The number of drops (10 per cent) from the check trees and the lack of increase of drops from the trees treated with the Pickering sprays used on plats A₁ and B₁, the two strongest of each formula with respect to percentage of copper sulphate, over those from the check trees lead to the conclusion that the high percentage of drops for the sprayed trees on plats B₂ and B₃ was not due to the sprays used.

Spray or late Bordeaux injury of apples.—Early in September a specking of the fruit on all the sprayed trees was noticed. This injury, known as spray or late Bordeaux injury, consisted of red spotting usually surrounding a lenticel, and generally found on the exposed side of the apple. On some apples the injury was so severe

as to cover the entire exposed cheek with a deep red blush, due to the coalescence of individual spots. This type of injury was common in this locality, particularly in those orchards which had been thoroughly sprayed with Bordeaux. It was most severe on the trees which had received the Pickering (A) spray, a little less severe on the trees treated with Pickering (C) spray, and very apparent on the Bordeaux-sprayed trees. The spotting or late Bordeaux injury, shown on all the sprayed trees, reduced the value of the 1917 crop. The unsprayed trees yielded the best fruit. The reduction of yield due to bitter rot was practically negligible.

IN 1918.

At the time of the third spraying, July 26, possibly 5 per cent of the leaves on the trees treated with the barium-water spray and some on the Pickering-sprayed trees and on the Bordeaux-sprayed trees showed a yellowing. The dry weather and heat during the previous four weeks may have been responsible for this yellowing which was not serious in any case. No injury to the apples was observed. At the time of picking no foliage injury of any consequence was observed on any of the plats. A brief outline of the theories advanced to explain the injury to foliage which frequently results from the application of copper sprays is given on page 27.

No results to show whether the sprays increased or decreased the yield are obtainable. The only available figures on yield are the records of the number of apples secured in connection with the bitter-rot counts, which are from but one tree of each plat.

SUMMARY.

In 1916 practically all of the fruit from the trees treated with Pickering and Bordeaux sprays and from the check trees was infected with bitter rot, which made it impossible to determine the relative efficacy of the Pickering sprays. Slight injury to the leaves and fruit on the Pickering-sprayed trees was noticed.

In 1917, Pickering (A) sprays containing 0.12, 0.25, and 0.5 per cent of copper sulphate injured apple leaves, and caused late Bordeaux injury to the fruit. Pickering (C) sprays of the same strengths produced less injury. Standard Bordeaux, 4-4-50, spray, containing 1 per cent of copper sulphate, also injured the leaves and russeted the fruit, although not as severely as the Pickering (C) spray. But little bitter rot was found on any of the Pickering- or Bordeaux-sprayed or check trees. Hence no control test of the sprays was obtained.

In 1918 no injury to the leaves or fruit resulted from the use of a Pickering (C) spray containing 0.58 per cent of copper sulphate,

from a barium-water spray containing 0.6 per cent of copper sulphate, or from standard Bordeaux, 4-4-50. The amount of bitter rot on the sprayed trees was so small that no definite control results were obtained.

The data on the control of bitter rot by Pickering (A) and (C) sprays are rather limited, notwithstanding the fact that the experiments extended over three seasons. However, 0.5 per cent of copper sulphate present in either Pickering (A) or (C) spray gave indications of satisfactory control of fungous diseases.

The Pickering (A) spray is too caustic for use on the apple. While less caustic than Pickering (A) sprays, the Pickering (C) sprays seem to be more caustic than standard Bordeaux. It is apparent that these sprays are more caustic than standard Bordeaux, and can not be used on the apple.

The barium-water spray was tested but one season on the apple. While the results were satisfactory with respect to the absence of injury, so little bitter rot was present on any of the trees that season that no definite control results were obtained.

Additional experiments are necessary to determine whether a Pickering spray containing more limewater than is required in Formula C and the barium-water spray may be safely and efficiently used as a fungicide on the apple.

CRANBERRIES.

CONTROL OF FUNGOUS DISEASES.

IN 1917.

Two Pickering (A) sprays and two Pickering (C) sprays were tested on Centennial cranberries in 1917 at Hanover Farms, N. J. The percentage of copper sulphate in the four sprays varied from 0.32 to 0.62. In addition, Bordeaux, $2\frac{1}{2}$ - $1\frac{1}{4}$ -50, $2\frac{1}{2}$ - $2\frac{1}{2}$ -50, and 4-3-50, sprays were used. The first two Bordeaux sprays were taken for the purpose of comparing the different amounts of lime in a Bordeaux spray with the amount in a Pickering spray of the same copper sulphate content (0.64 per cent).

The sprays were applied to small plats, 132 feet long and $8\frac{1}{4}$ feet wide, with a hand-pump sprayer, four times during the season, June 14 (three or four days before full bloom), June 27 (10 days after full bloom), July 13, and July 30. Rosin-fish-oil soap, at the rate of 2 pounds to 50 gallons, was mixed with all the sprays. The berries were picked September 15 and sorted for rot soon afterwards.

TABLE 12.—*Effect of various sprays on rot and yield of cranberries (New Jersey).*¹

Plat No.	Spray used.	Copper sul- phate in spray used.	Total yield.				Yield per acre (calculated).	
			All berries.	Rotten berries.		All berries.	Sound berries.	
		Per ct.	Pounds.	Pounds.	Per ct.	Bushels.	Bushels.	
1917.								
1	Pickering (A)	0.32	67½		4.8		80	
2	Pickering (C)	.40	57		6.5		66½	
3	do.	.54	55½		5.4		66	
4	Pickering (A)	.62	53½		5.8		62½	
5	Bordeaux, 4-3-50.	1.00	50½		5.6		59½	
6	Bordeaux, 2½-1½-50.	.64	73½		4.4		88½	
7	Bordeaux, 2½-2½-50.	.64	59½		5.1		70½	
8 (check)			78½		12.0		86½	
A.	Pickering (A)	.6	19½	1½	4.2			
B.	Bordeaux, 4-3-50.	1.00	19½	1½	2.8			
1918.								
1	Sal soda and rosin-fish-oil soap, 4-5-50.	1.00	54½	6½	11.9	136½	120½	
2	Sal soda and fish-oil emulsion, 4-5-50.	1.00	68½	5	7.3	171½	158½	
3 (check)			41½	6½	15.1	207½	176½	
4	Barium water and rosin-fish-oil soap.	.6	80½	13	16.1	201½	163½	
5	Pickering (C) and rosin-fish-oil soap.	.6	107½	20½	19.1	268	216½	
6	Pickering (A) and rosin-fish-oil soap.	.6	94½	20½	20.8	235½	184½	
7 (check)			38	26½	69.7	190	57½	
8	Bordeaux, 4-3-50, and rosin-fish-oil soap.	1.00	74½	12	16.2	185½	155½	
9	Bordeaux, 4-2-50, and rosin-fish-oil soap.	1.00	59½	5½	9.7	148½	134½	
10	Bordeaux, 4-1-50, and rosin-fish-oil soap.	1.00	64½	8½	12.8	161½	140½	

¹ All the cranberries tested were of the Centennial variety, except those on plats A and B, which were Early Black.

The percentage of rot found on the berries from all of the sprayed plats (Table 12) was so small that it was impossible to differentiate between the sprays with respect to their fungicidal value. The check plat showed but 12 per cent of rot. The Bordeaux, 2½-1½-50, spray gave the best results for control of rot, but all of the other sprays were almost as good. On the large plats (A and B) 4.2 per cent of rot was found for berries treated with the spray resembling a Pickering spray and 2.8 per cent for those treated with Bordeaux. While the data favor the standard Bordeaux spray, the figures are small.

Two large plats (A and B) of Early Blacks were sprayed with a power sprayer, one receiving Bordeaux, 4-3-50, the regular spray used on cranberries at Hanover Farms, and the other a spray resembling a Pickering spray of 0.6 per cent copper sulphate content, made by dissolving in water an amount of lime paste calculated from titrations to be sufficient to combine with the copper sulphate used. The results thus obtained are not comparable with those obtained from plats 1 to 8 (Table 12).

IN 1918.

Ten small plats of Centennial berries at Hanover Farms, N. J., were sprayed with a barrel-pump sprayer on June 11 (three or four days

before full bloom), June 25 (10 days after full bloom), July 24, and August 12. The small plats were separated by four-foot paths over which the spray apparatus was drawn, thus protecting the berries on the sprayed plats from injury like that received in 1917. The vines on plats 5 and 6 were heavier than those on the other plats. Pickering (A) and (C) sprays, a barium-water spray, two sal-soda (Na_2CO_3) sprays, and three sprays of the Bordeaux type, made with 1 per cent of copper sulphate and varying amounts of lime, were employed (Table 12). The sal-soda (Na_2CO_3) and fish-oil-emulsion spray was prepared by shaking together 1 ounce of water and an equal amount of fish oil until emulsified, and then stirring it into the spray. The barium-water spray was prepared by the use of barium hydrate in place of lime (p. 16). The Pickering (C) spray was made with an excess of limewater, and the Pickering (A) spray with just the amount of limewater required to neutralize all the copper sulphate present (p. 3).

As shown by the figures for rotten berries, 15.1 and 69.7 per cent for the check plats (Nos. 3 and 7), the amount of rot varied greatly. The lowest percentage of rotten berries was obtained on plat 2, where sal-soda and fish-oil-emulsion spray was used.

The following notes were taken on September 5:

Plat 1.—The sal-soda spray resembles the Bordeaux, 4-3-50, spray used on plat 8.

Plat 2.—The berries look sound. More spray is seen on berries than on those in plat 1. It occurs in isolated spots or freckles, rather than in a continuous layer, as is the case with the spray on plat 1.

Plat 3.—Berries are quite sound. Not over 5 per cent of rot is visible.

Plat 4.—Spray is seen distinctly over entire plat. It is the only plat that looks blue at a distance. Good protection is afforded, although there is more rot than on plats 1 and 2. The spray shows regularly on the berries, but is not of uniform density. The berries with spray have a festooned appearance, as if each drop of spray on drying was thickest at the periphery.

Plat 5.—But few rotten berries seen. Spray shows plainly in spots.

Plat 6.—Same as plat 5.

Plat 7.—Estimated 50 per cent rot.

Plat 8.—Berries very sound. A little more spray visible than on either plat 5 or 6.

Plat 9.—Generally like plat 8. Spray somewhat more apparent. Vines not quite as thick as on most of the other plats.

Plat 10.—Spray shows about like that on plat 9. The northern end of the plat is poor land and shows more rot. Rest of plat is very sound.

More spray was observed on the plat treated with Bordeaux, 4-3-50, than on those sprayed with the Pickering sprays. It is difficult to explain the results obtained with the barium-water spray, which, judging from the figures for rot control, produced no effect. This spray gave an excellent control of fungous diseases on potatoes, as compared with a Bordeaux, 5-5-50. Pickering (A) and (C) sprays on plats 5 and 6, where the vines were very dense, showed practically identical fungicidal power. The sprays used on plats 8, 9, and 10 showed good control of rot. From a comparison of results with sprays used on plats 8, 9, and 10, it is impossible to determine the influence of the different amounts of lime on the fungicidal properties of the 1 per cent copper sulphate present in the three sprays.

Included in the 1918 tests were three commercially-sprayed plats, treated with a Pickering (C) spray containing 0.6 per cent of copper sulphate, a Bordeaux spray made with 0.6 per cent copper sulphate, and a Bordeaux, 4-3-50, containing 1 per cent copper sulphate, such as is regularly employed for spraying cranberries at Hanover Farms. Two hundred gallons of each spray were made and applied with the power spray apparatus to Early Blacks. Rosin-fish-oil soap was used with all three sprays. The sprays were applied three times, June 13, July 3, and July 24. Very little rot was seen on any of the plats, and at the time of picking no differences in control of rot on the three plats were evident. No check plat was employed.

YIELD.

IN 1917.

The calculation of the results for yield of the Centennial berries (Table 12) was complicated by injury to the berries due to drawing the spray apparatus over the vines four times. The high figure for yield on the check plat is in part explained by the fact that none of the berries on this plat were crushed by the spray cart. Unavoidable irregularities occur in the yields of all plats of cranberries of any size. The yield results on Early Blacks are so close that no conclusions can be drawn as to the influence of the sprays on the yields of berries.

IN 1918.

No results which show the influence of the sprays on the yields of cranberries are available.

ADHERENCE OF COPPER FROM VARIOUS SPRAYS TO LEAVES.

IN 1917.

Samples of cranberry leaves were gathered on July 10, two weeks after the third spray had been applied, and on September 4, five weeks after the fourth spraying, and analyzed (Table 13).

TABLE 13.—*Adherence of copper from various sprays to cranberry leaves (New Jersey).*

Plat No.	Spray used.	Copper sulphate in spray used.	Time between spraying and gathering.	Amount of copper.	
				Parts per million (dry basis).	Parts per million per 0.1 percent of copper sulphate in spray.
1917.		<i>Per cent.</i>	<i>Days.</i>		
1	Pickering (A)	0.32	14	110.8	35
2	Pickering (C)	.405	14	140.2	35
3	do	.54	14	167.2	31
4	Pickering (A)	.64	14	166.2	26
5	Bordeaux, 4-3-50.	1.00	14	680.2	68
6	Bordeaux, 2½-1½-50	.64	14	407.8	64
7	Bordeaux, 2½-2½-50.	.64	14	385.4	60
8 (check)				32.6	
1	Pickering (A)	.32	35	80.0	25
2	Pickering (C)	.405	35	100.7	25
3	do	.54	35	146.7	27
4	Pickering (A)	.64	35	131.3	21
5	Bordeaux, 4-3-50.	1.00	35	429.0	43
6	Bordeaux, 2½-1½-50.	.64	35	138.0	21
7	Bordeaux, 2½-2½-50.	.64	35	323.4	51
8 (check)					
1918.					
1	Salsoda and rosin-fish-oil soap	1.0	0	1,200	120
2	Salsoda and fish-oil emulsion	1.0	0	1,300	130
4	Barium water and soap	.6	0	1,100	183.3
5	Pickering (C) and soap	.6	0	1,100	183.3
6	Pickering (A) and soap	.6	0	1,400	233.3
7 (check)				47	
8	Bordeaux, 4-3-50, and soap	1.0	0	1,600	160
9	Bordeaux, 4-2-50, and soap	1.0	0	1,800	180
10	Bordeaux, 4-1-50, and soap	1.0	0	1,600	160
1	Salsoda and rosin-fish-oil soap	1.0	28	330	33
2	Salsoda and fish-oil emulsion	1.0	28	380	38
4	Barium water and soap	.6	28	210	35
5	Pickering (C) and soap	.6	28	630	105
6	Pickering (A) and soap	.6	28	370	61.7
7 (check)				17	
8	Bordeaux, 4-3-50, and soap	1.0	28	840	84
9	Bordeaux, 4-2-50, and soap	1.0	28	1,000	100
10	Bordeaux, 4-1-50, and soap	1.0	28	860	86

The leaves sprayed with Bordeaux held a higher percentage of copper than those sprayed with the Pickering sprays, indicating that the extra lime of the Bordeaux spray, at least where rosin-fish-oil soap was used, is an important factor in increasing the adhesive properties of the spray on cranberry leaves. Possibly the copper of the Pickering sprays was more efficient as a fungicide per unit of copper present in the sprays than that of the standard Bordeaux spray, although the copper of the Pickering sprays did not adhere to the leaves as well as that of the Bordeaux sprays. The results for control of rot favor this view. The percentage of rotten berries (Table 12) does not speak particularly well for the sprays used on Plats 5 and 7, in spite of the fact that the leaves receiving these sprays retained the largest amounts of copper (Table 13). The results given in Table 13 show nothing concerning the distribution of the copper on the leaves or the form and efficacy of the copper on the leaves.

IN 1918.

One set of sprayed cranberry leaves was gathered for analysis for copper on June 25, directly after the sprays had been applied, and a

second set on July 24, four weeks after the last sprays had been applied (Table 13).

The most actual copper was found on the leaves sprayed with Bordeaux containing 1 per cent of copper sulphate (plats 8, 9, and 10). Calculated per 0.1 per cent of copper sulphate present in the sprays, the leaves from plats 4, 5, and 6, sprayed with the two Pickering sprays and the barium-water spray, and gathered directly after the sprays had been applied, gave the highest results. Of the leaves gathered four weeks after spraying, those treated with the Bordeaux sprays (plats 8, 9, and 10) and with the Pickering sprays (plats 5 and 6) gave the highest proportional results. The barium-water spray and the two sprays made with sal soda did not adhere to the leaves for the four-week period as well as the sprays made with lime. The percentage of rotten berries found on the two plats sprayed with the sal-soda sprays was low, in spite of the relatively small amounts of copper adhering to the leaves at the time of analysis. Apparently, therefore, the amount of copper adhering to a leaf is not necessarily a criterion of its protection from fungous diseases.

INJURY TO LEAVES AND FRUIT.

No caustic action of any of the sprays was noted in either 1917 or 1918.

SUMMARY.

None of the sprays tested injured the leaves or berries.

The Pickering (A) and (C) sprays were equally effective in controlling fungous diseases. Pickering (A) and (C) sprays prepared with 0.6 per cent of copper sulphate seemed to give as effective control of fungous diseases on cranberries as Bordeaux, 4-3-50, containing 1 per cent of copper sulphate, although this was not definitely proven.

Practically the same percentage of copper was present on the cranberry leaves treated with Pickering spray as on those sprayed with standard Bordeaux, rosin-fish-oil soap being used with all the sprays.

Additional tests with the Pickering, barium-water, and sal-soda sprays are necessary to obtain conclusive results.

SUGGESTIONS FOR THE PREPARATION OF PICKERING SPRAY ON A COMMERCIAL SCALE.

The following procedure is recommended for the preparation on a commercial scale of a Pickering (A) spray containing 0.7 per cent of copper sulphate:

STOCK SOLUTION OF COPPER SULPHATE (BLUESTONE OR BLUE VITRIOL).

Suspend 50 pounds of commercial crystalline copper sulphate in a gunny sack in 20 or 30 gallons of water in a clean barrel over

night, placing the copper sulphate just beneath the surface of the water. This may be conveniently done the evening before the spray is to be applied. Remove the gunny sack, stir the solution of copper sulphate with a wooden paddle, make to 50 gallons with water, and stir again. Keep the barrel or container covered. The barrel or container must not leak. The solution thus prepared contains 1 pound of copper sulphate per gallon. Smaller amounts of the copper sulphate may be dissolved, using the same proportions of copper sulphate and water

SATURATED LIMEWATER.

Place 2 pounds of unslaked lime of a good grade in a clean barrel or other wooden container, sprinkle with a little water, and let stand. In a few minutes, when the lime crumbles, add 2 or 3 quarts of water. Stir the lime and water until a smooth paste is formed, adding a little more water if needed. Finally, fill the barrel and stir six or eight times, allowing the insoluble particles of the lime to settle after

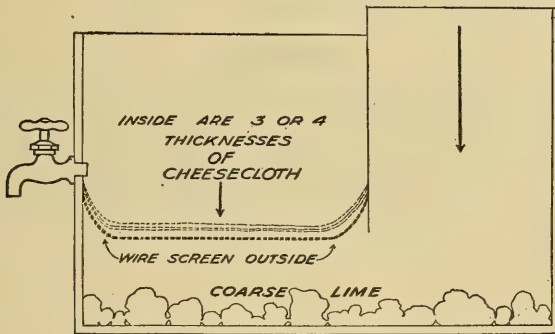


FIG. 1.—Apparatus for filtering limewater.

each stirring. Then cover and let stand until used. The limewater may be drawn from the barrel by means of a faucet placed 3 or 4 inches from the bottom. The limewater should be passed through a strainer (fig. 1) before it is allowed to flow into the mixing tank. If preferred, the clear limewater may be siphoned off from the top of the barrel directly into the mixing tank.

In making limewater for spraying on a commercial scale, several pounds of lime may be slaked in a large tank, water added, and the mixture stirred by means of a mechanical stirrer for 5 or 10 minutes. The clear limewater may be drawn from the top of the tank almost immediately by arranging a float with attached hose. If from 15 to 20 minutes are allowed for the lime particles to settle, the clear limewater may be drawn from a spigot placed 6 or 8 inches from the bottom of the tank. If desired, slaked lime may be placed in barrels, allowing about 4 pounds of paste to a barrel, water added, and the mixture in each barrel stirred six or eight times in turn. The suspended particles will settle in about 10 minutes, when the clear

limewater may be drawn off by suction through a hose into the mixing tank or barrel.

In making saturated limewater, 2 pounds of unslaked lime, or 4 pounds of lime paste, to 50 gallons of water are sufficient.

MIXING.

Add 23.1 quarts of the standard copper sulphate solution (1 pound to a gallon) to a 100-gallon tank containing 93.78 gallons of clear saturated limewater, and stir for 1 minute. Lead arsenate or calcium arsenate may then be added if desired, and 0.42 gallon of water to make the volume to 100 gallons.

The method of preparing limewater is the principal distinction between making the Pickering and the standard Bordeaux sprays.

In the experience of the writer, the Pickering sprays are readily prepared, in much less time than many of the proprietary pastes which dissolve with difficulty, and take but little more time than the standard Bordeaux sprays require.

SUMMARY.

Experiments covering three seasons were conducted with Pickering (A) and (C) sprays, made to contain from 0.06 to 0.70 per cent of copper sulphate. The efficacy of these sprays was compared with that of standard Bordeaux mixtures containing from 0.75 to 1.25 per cent of copper sulphate. The investigation was carried out under American field conditions, in regions where certain fungous diseases are most severe.

The strongest Pickering sprays, those containing from 0.6 to 0.7 per cent of copper sulphate, controlled fungous diseases on potatoes and cranberries very effectively. Their control of fungous diseases on grapes and apples was not definitely determined, the results being complicated by burning or other injury to the foliage and fruit. Pickering sprays containing less than 0.6 per cent of copper sulphate were not effective as fungicides for potatoes and probably not for cranberries. No difference between the efficacy of the Pickering (A) sprays and that of the Pickering (C) sprays was observed. The results of the tests made on potatoes indicated that per unit of copper present the Pickering sprays were twice as effective as the Bordeaux mixture. No evidence, however, was found to substantiate the claims of Bedford and Pickering (3, 4) that they were from 12 to 15 times as efficient as the standard Bordeaux sprays. As long as enough lime to combine with the copper was present, the reduction of the lime content of Bordeaux sprays did not alter their fungicidal value.

Increased yields of tubers were obtained on plats of potatoes treated with Bordeaux and with the stronger Pickering sprays, in-

dicating that these sprays exerted similar stimulating and protective action on potato plants.

The adhesive properties of Pickering sprays varied with the foliage to which they were applied. They adhered to potato and cranberry leaves in practically the same degree as the standard Bordeaux, to apple leaves in a somewhat higher proportion, and to grape leaves in a lower proportion.

No injurious effects followed the application of Pickering sprays to potatoes in Maine or to cranberries in New Jersey. The sprays, however, proved to be too caustic for use on the apple in Virginia or on grapes in New Jersey and Virginia. Pickering sprays can not be used on tender foliage.

Barium-water sprays of the Pickering type, made with barium hydrate instead of lime and containing 0.7 per cent of copper sulphate, proved very successful as a fungicide for potatoes. Such a spray containing 0.6 per cent of copper sulphate did not injure the foliage or fruit of the apple tree.

These results are presented as the basis for further studies to be conducted in various parts of the country. It is believed that from this material agricultural experiment stations and other agencies will be able to devise formulas for sprays for certain crops containing less copper sulphate than standard Bordeaux, which will prove just as effective as the more expensive spray.

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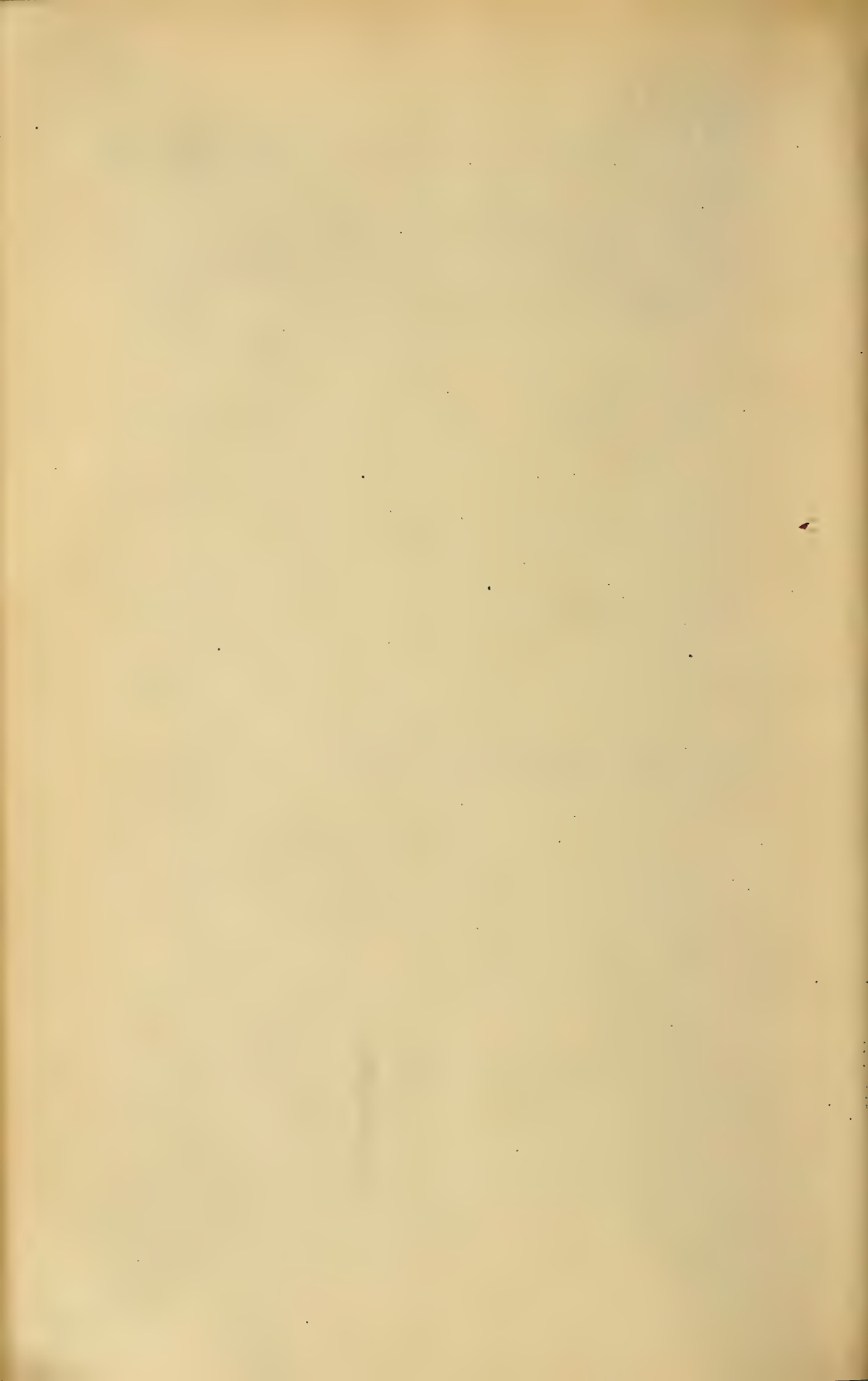
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PROFESSIONAL PAPER

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THE CASTOR-OIL INDUSTRY.

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THE SOURCE OF CASTOR OIL.

Castor oil is obtained from the seeds of the castor-oil plant (*Ricinus communis*), a member of the plant family Euphorbiaceæ, which also includes many other species the seeds of which yield fatty oil. The castor-oil plant is now either cultivated or found growing wild in most tropical countries and in the milder parts of the Temperate Zones. In warm countries it is a perennial and often attains the proportions of a tree, frequently reaching a height of 40 feet, but in colder climates it rarely grows 20 feet high and annually dies down with the approach of winter. This plant is extremely variable in size, color of stems and leaves, degree of branching, size and color marking of the seeds, and many other characteristics.

The seeds of the castor-oil plant are known as "castor beans" in English-speaking countries, and are often mistakenly supposed to belong to the bean family, to which they are in nowise related. Castor beans as they occur in commerce consist of a white, soft, nonfibrous kernel inclosed in a hard, thin seed coat. This is so brittle that unless care is exercised in handling, it is easily cracked and chipped off, exposing the kernel to the air, with attendant deterioration. This seed coat is usually mottled in appearance and varies in color from a creamy white through pink, golden yellow, green, and

brown to black. The beans vary in weight from 0.10 gm. to 1.22 gm., and in size from 7.5 mm. long by 50 mm. wide by 4.5 mm. thick to 23 mm. by 15 mm. by 8 mm., respectively. One cubic foot of beans of average size weighs about 37 pounds.

An analysis of a commercial sample of castor beans shows that the whole bean consists of 35 per cent of seed coat and 65 per cent of kernel, the oil content of these two parts being 10 and 62.9 per cent, respectively.

Analyses of 37 samples of castor beans imported from India, China, the West Indies, and South America show a range of oil content, determined by ether extraction, from 38.39 to 55.55 per cent, with an average value of 48.75 per cent. Similar assay of 50 samples of beans from the first American crop from imported seed in 1918 shows a range of 42.13 to 58.57 per cent, averaging 48.16 per cent. With present milling practices there is obtained about 15.6 pounds of No. 1 oil per 46-pound bushel, 4.1 pounds of No. 3 oil, and 25.5 pounds of pomace, with a shrinkage per bushel of about 0.8 pound.

Castor beans contain a poisonous principle which renders them extremely dangerous when eaten. Also picking off the seed coats with the fingers has been followed by inflammation and soreness under the finger nails. Persons who have weak eyes or who are subject to hay fever may suffer serious inconvenience, to say the least, following exposure to the dust from ground dried castor pomace.

The common belief that the coloring matter occurring in castor oil extracted by the solvent process is introduced through the so-called germ has not been borne out by experiments. On the contrary, the color seems to be mostly derived from the seed coats. It is observed that decorticated kernels yield a light-colored oil when extracted by volatile solvents, while the whole bean or the seed coats alone yield progressively more highly colored oils. But the coloring matter is evidently not a single simple substance, for upon extraction with different solvents different colors are obtained. Benzol gives a green-colored oil, gasoline a yellowish oil, while methyl ethyl ketone, acetone, ethyl alcohol, and methyl acetate all yield a red-colored oil which slowly turns to dark brown on exposure to the air.

Castor beans also contain the enzym lipase, which is extremely active in hydrolyzing the oil to glycerin and free fatty acid. This action does not occur so long as the seed coat remains intact and protects the kernel from exposure to the air, but when the seed coat is broken the enzym quickly begins its hydrolytic action. Since broken and damaged beans when crushed yield a highly colored acid oil, care must be exercised in hulling and shipping to avoid breaking the seed coats.

Another factor contributing to the high acidity of castor oil is what are known as black beans. These are rancid beans, the kernels of

which have turned brown. Table I presents a comparison of the acidity of carefully selected beans with that of a mixture containing a known number and weight of black beans.

TABLE I.—*Comparison of the acidity of carefully selected castor beans with that of a mixture containing a known number and weight of black beans.*

Source.	Black beans in mixture by number.	Acidity (as oleic acid).	Source.	Black beans in mixture by number.	Acidity (as oleic acid).
	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>
Miscellaneous imported lot....	0	0.9	Brazil.....	0	1.4
	26	2		15	4.6
	50	7.7		24	3.3
	75	6	Bombay.....	0	1.2
	100	13		8.2	1.5
Do.....	0	1.1	Haiti.....	0	.6
	16	2.4		15	1
	50	8.1	Venezuela.....	0	1
				10.7	2.1

It is interesting to note that in no case, even when all the beans were perfectly whole (controls), did the acidity as determined by titrating run below 0.6 per cent. Consequently, since at least a small amount of acid is invariably present, an acid determination of carefully selected sound beans would give a correct idea of the degree of freedom from acidity possible were all the beans equally sound. This percentage could not, of course, be realized in actual commercial practice, but it would show the standard toward which to work.

TRADE AND COMMERCE.

The normal annual consumption of castor oil in the United States is more than 2,000,000 gallons, almost all of which is produced by our own crushing plants. The average annual importation of castor beans for the five fiscal years ended June 30, 1917, was about 834,000 bushels, while the importations of oil as such were comparatively insignificant.

The castor beans and castor oil of commerce come chiefly from India, China, the West Indies, and South America, with India producing by far the greatest quantity. In 1913 India exported 954,495 gallons of oil, while in 1917 this trade had increased to 1,723,463 gallons,¹ approximately 80 per cent of which was exported to the United Kingdom, 9 per cent to New Zealand, and 8 per cent to Australia. The center of the oil industry in India is Madras, which produces about 60 per cent of the total. Before the war the center of the industry was Bengal, which produced about 90 per cent of the castor oil exported. Table II gives the total exports of castor beans and castor oil from India for the years 1911-12 to 1917-18.

¹ These figures were supplied by the Far Eastern Division of the Bureau of Foreign and Domestic Commerce, February 21, 1919.

TABLE II.—Exports of castor beans and castor oil from India for the years 1911-12 to 1917-18, inclusive.¹

Year.	Beans.	Oil.	Year.	Beans.	Oil.
	<i>Tons.</i>	<i>Gallons.</i>		<i>Tons.</i>	<i>Gallons.</i>
1911-12.....	120, 194	1, 404, 803	1915-16.....	87, 950	1, 451, 655
1912-13.....	110, 630	954, 495	1916-17.....	92, 447	1, 723, 469
1913-14.....	134, 888	1, 007, 001	1917-18.....	86, 100	2, 086, 038
1914-15.....	82, 815	898, 269			

¹ Castor oil for aircraft engines. *In Jour. Soc. Chem. Indus.*, v. 38, no. 2, p. 20R-21R. 1919.

Approximately 95 per cent of the castor beans exported were shipped out of Bombay. England took 4 per cent, the United States 23 per cent, France 18 per cent, Italy 47 per cent, and all other countries 8 per cent.

TABLE III.—Imports of castor beans into the United States from various sources during the fiscal years 1910 to 1918, inclusive.¹

Country.	Imports of castor beans.								
	1910	1911	1912	1913	1914	1915	1916	1917	1918
France..... bushels..	2	2	1		1		22		
Germany..... do.....	2		108		3				
Italy..... do.....	12	14	2	5	27	21			
Netherlands..... do.....	1	1	3						
United Kingdom..... do.....	503, 773	368, 966	135, 137	43, 392	105, 390	163, 267	223, 208	91, 007	607
Canada..... do.....	2	2						1	
Cuba..... do.....	1, 556								
Dutch West Indies..... do.....	5, 729	8, 165	984	1, 669	3, 136				1, 587
Santo Domingo..... do.....		102	3						
Brazil..... do.....	158, 351	122, 918	44, 633	8, 961	10, 049	9, 744	7, 887	94, 148	169, 312
British Guiana..... do.....	28								
Venezuela..... do.....	2, 839	1, 930				789		540	14, 367
British India..... do.....	53, 707	242, 935	777, 074	833, 720	905, 946	750, 039	839, 282	517, 711	620, 480
Jamaica (British West Indies), bushels.....			41		131	59			
Turkey in Europe..... bushels.....					2, 229				
Other British West Indies, bushels.....					13				32
China..... bushels.....					3		1, 542		28
Dutch East Indies..... do.....					3, 610	685	14	263	
Japan..... do.....					5			10, 284	124, 793
Honduras..... do.....								2	
Mexico..... do.....								39	2, 541
Dominican Republic..... do.....								58	608
Haiti..... do.....								1, 242	80, 687
Argentina..... do.....								13, 275	9, 067
Colombia..... do.....								400	771
Japan (Chinese leased territory)..... bushels.....								37, 887	13, 426
Hongkong..... do.....								2	4, 295
Costa Rica..... do.....								6	212
Panama..... do.....									256
Trinidad and Tobago..... do.....									21
Peru..... do.....									824
Uruguay..... do.....									1
British South Africa..... do.....									79
Total..... (do.....)	726, 002	745, 035	957, 986	887, 747	1, 030, 543	924, 604	1, 071, 963	766, 857	1, 444, 014
	(tons.....)	16, 698	17, 136	22, 034	20, 418	23, 702	21, 266	24, 655	17, 638

¹ These figures are taken from "General imports" in Commerce and Navigation of the United States and represent the bushel as containing 50 pounds of beans.

Castor beans grow quite abundantly all over China. Reports from United States consuls show that the total exportation of castor oil from seven ports in 1913 was 3,677,266 pounds, while in 1916 the

total for these same ports reached 9,108,133 pounds. These ports in the order of their importance, with percentages, are as follows: Tientsin, 45; Shanghai, 19; Newchwang, 17; Kiaochow, 11; Dairen, 5; Hankow, 3; Canton, negligible.

Owing to the campaigns inaugurated by the Allies to increase the world's production of castor beans, notable quantities of beans and some oil have been entering the world's commerce from Central America, Africa, Japan, and the Malay Archipelago. Table III gives the imports of castor beans from various sources into the United States during the fiscal years 1910 to 1918, inclusive.

The castor beans and castor oil imported for consumption during the fiscal years 1910 to 1919, inclusive, minus the quantities exported, are presented in Table IV. Inasmuch as there was during this period practically no American commercial production of castor beans, these figures fairly represent our trade in this commodity. It was only during 1918 that there was really a commercial American crop, and this was due to the demand for oil for aircraft lubrication.

TABLE IV.—*Castor beans and castor oil imported for consumption, minus the quantities exported, during the fiscal years 1910 to 1919, inclusive.*¹

Fiscal year.	Castor beans (bushels).	Castor oil (gallons).	Total as oil.		Fiscal year.	Castor beans (bushels).	Castor oil (gallons).	Total as oil.	
			Gallons.	Pounds.				Gallons.	Pounds.
1910...	752,374	.....	2,106,647	16,853,176	1915..	924,605	63,005	2,651,899	21,215,192
1911...	790,241	.....	2,212,675	17,701,400	1916..	1,071,969	253,077	3,354,590	26,036,720
1912...	978,257	6,971	2,746,090	21,968,720	1917..	767,019	323,703	2,471,456	19,770,848
1913...	824,573	5,241	2,314,045	18,512,360	1918..	1,262,130	1,175,064	4,709,028	37,672,224
1914...	1,043,928	189,583	3,112,591	24,900,728	1919..	628,312	.....	1,759,274	14,074,192

¹ These figures are taken from "Imports for consumption" in Commerce and Navigation of the United States, and represent the bushel as containing 50 pounds of beans, yielding 45 per cent of oil, or 22.5 pounds, which is equivalent to about 2.8 gallons of oil.

From November, 1918, to June, 1919, inclusive, the Government plant at Gainesville, Fla., was crushing American-grown castor beans. It crushed 211,000 bushels (of 46 pounds), yielding 463,000 gallons of oil, or 3,730,000 pounds. This quantity, of course, is to be added to that produced by the regular castor-bean crushing industry from imported beans, reported above, to show the total consumption and stocks for the fiscal year 1918-19. In the winter of 1917-18 about 6,000 bushels of imported castor beans were used for planting.

The rate of duty on castor beans from August 5, 1909, to October 4, 1913, was 25 cents per bushel; subsequent to that date it was 15 cents. The duty on the oil for corresponding dates was 35 and 12 cents per gallon.

In 1912, 88 per cent of the beans imported entered at New York, 8 per cent at Grand Rapids, and 4 per cent at Boston. Table V

shows the relative quantities of beans imported from various sources for the years 1912, 1914, and 1918.

TABLE V.—*Relative quantities of castor beans imported from various sources during the years 1912, 1914, and 1918.*¹

Source.	Relative importations of castor beans (per cent).		
	1912	1914	1918
United Kingdom.....	14.0	10.0	0.06
India.....	81.0	87.9	60.00
South America.....	4.6	1.0	19.00
West Indies.....	.1	.3	8.00

¹ Calculated from Table III.

In 1918 the American castor-bean crop was estimated at about 5,750 tons (250,000 bushels), or about one-fourth of the normal domestic consumption. The sudden cessation of hostilities, however, together with the great impetus given to castor-bean cultivation throughout the world, has resulted in an overburdened market, with consequent tendencies to lower the price and unload foreign stocks in the United States. This would certainly have a tendency to cripple the crushing industry here were it not for the high quality of oil produced. In fact, the best grade produced in this country is not excelled by any foreign producer, while some of our No. 3 grade is as good as much of the imported first-grade oil. However, there is a growing tendency among foreign vegetable-oil producers to erect crushing mills near the areas of production of oleaginous materials, which would certainly seem in course of time to affect our supplies of raw material, with the consequent crippling of our mills.

The relieving feature of this development is the intimate knowledge gained of the possibilities for creating a permanent American castor-bean industry. In the past this has been an actuality. Until about 1900 relatively large quantities of castor beans were raised in this country,¹ chiefly in Oklahoma, Kansas, Missouri, and Illinois, but in the face of successful foreign competition the possibilities for development of the American crop disappeared. The great campaign of castor-bean growing inaugurated in 1917 by the Bureau of Aircraft Production has resulted in gathering considerable information concerning the growing of castor beans, such as yields per acre in different parts of the country and cost of handling, and we are now in a good position from the standpoint of knowledge of farming conditions to adopt intelligently whatever measures may be necessary to meet foreign competition. Most of the details of seed

¹ Yearbook, U. S. Dept. of Agriculture, 1904, p. 295.

selection and methods of planting, cultivating, and harvesting are being worked out. But the farmer who would raise castor beans as a crop will have to be shown that he can receive more money per acre than he is receiving from his present crops before there will be a satisfactory home production of castor beans. Cost, yield, market, and profit are the determining factors.

The relative consumption of castor beans in the great vegetable-oil producing countries for the years 1911 to 1913 is shown in Table VI. Exports are subtracted from imports, all figures being reported in the respective commerce returns.

TABLE VI.—*Consumption of castor beans in the great vegetable-oil producing countries for the years 1911, 1912, and 1913.*

Countries.	Consumption of castor beans (bushels).		
	1911	1912	1913
United States.....	790,000	978,000	824,000
United Kingdom ¹	1,928,000	1,856,000	2,132,000
France ²	460,360	663,520	1,006,280
Germany ³	336,760	377,720	419,160

¹ Annual return of trade.

² Tableau général du Commerce et de la Navigation.

³ Auswärtige Handel-Statistik des Deutschen Reichs.

The United Kingdom exported much of its home-crushed oil, leaving 3,624,000 gallons (14,495 tons) of oil consumed in 1913, figured by subtracting the exports from the imports, whether oil as such or calculated on a 45 per cent yield from the beans. The American consumption in the same year, 1913, figured similarly, was 2,314,045 gallons (9,250 tons). (See Table IV.) The figures for France and Germany only very roughly follow consumption, as the customs returns include this commodity with others. Hence the figures represent a maximum never attained by castor beans alone.

THE INSPECTION OR VALUATION OF CASTOR BEANS.¹

The castor beans of commerce are bought on a standard form of contract of the Linseed Oil Association in New York City.² If 3 per cent of impurities, or less, is present in any lot of beans no deduction or reward for impurities is made, but if more than 3 per cent is present a deduction is made for all over such a figure. These impurities include hulls, sand, and pebbles, sometimes stones 2 or 3 inches in diameter, occasionally extraneous seeds, and even foreign money. Beans from India usually run well under 3 per cent of impurities,

¹ Contributed by A. C. Goetz (Capt. A. S. Sig. R. C.), formerly in charge of the Chemical Supplies and Materials Section of the Production Division, Inspection Department, Bureau of Aircraft Production.

² The Linseed Oil Association of New York City is an association of crushers, brokers, commission men, etc., dealing in linseed oil, castor beans, and other oleaginous materials.

but those from South America and the West Indies as a rule contain more dirt and trash than the beans from India. Shipments may also contain immature beans, decorticated beans, black beans, and broken beans. The decortication is done in the thrashing. Black beans (usually yellow, brown, or black) are those whose kernels have become discolored as the result of the beans having been wet. In imported lots, broken and decorticated beans as a rule are not excessive, but if the percentage of such black beans does run high, a claim is made, about 5 per cent being the maximum allowable figure. Broken and decorticated beans are not classed as dirt or impurities, but if the percentage seems excessive the claim for reduction is made independent of the percentage of trash. Black, broken, and decorticated beans have the effect of increasing the acidity of the oil produced therefrom.

Shipments of castor beans are sampled by commercial samplers. This is done by means of a tryer, samples being taken from 5 per cent of the bags in a lot, but no sample should be less than 50 pounds. The sample is divided into as many smaller ones as are necessary, one for analysis, one for record or file, and one for the purchaser or seller if he so desires. After the sample is obtained it is entirely in the hands of the Linseed Oil Association, which association makes the necessary records and arranges for an analysis by its official analyst. This analysis is accepted by both buyer and seller. Any dispute arising regarding the percentage of impurities or the quality of the beans is usually settled by the interested parties themselves, although the custom of the trade of having a committee or referee appointed is sometimes resorted to. As a rule, no beans are refused outright; usually any lot of beans will be taken at some price. If resort is taken to a committee or referee, the disputes as to quality are not settled in this country but are settled by the Oil Seeds Association of London, England, which considers the fair average quality of the season's crop. Such instances, however, are not frequent.

The weight per standard bushel is another factor indicative of the quality of castor beans. This weight varies with beans from different localities. Considering beans from the same locality, the heavier the weight per bushel the better the quality of the beans.

Inasmuch as castor beans are bought for oil making, it would seem that the logical way to judge them would be on the quantity and quality of the oil actually contained in the beans, in addition to the test for impurities, all of which the buyer should know before purchasing. He would then not be obliged to judge the oil in the beans on only an approximation. Such a method of purchase and inspection might require a longer time to complete tests, but they should be completed within 24 hours from the receipt of the sample, which does not seem impracticable. Oil-bearing seeds and material are

not yet bought on the above-suggested basis, but sooner or later such will doubtless be the practice. The only objection to this seems to be the desire of those interested not to change present methods, fearing that complications would be added to transactions unfavorable to growth in trade.

MANUFACTURE OF CASTOR OIL.

CLEANING.

The castor beans of commerce come mixed with such amounts of trash that it is absolutely necessary to remove this at the earliest stages of the operation. An ordinary grain cleaner is used, with special perforations in the screens for castor beans. These cleaners are a combination of screens and fans, which remove the straw, hulls, and dirt in successive operations of sieving and fanning and deliver the cleaned beans. Such machines vary greatly in size, with attendant capacities of 30 to 1,200 bushels of beans per hour.

DECORTICATION.

Owing to the peculiar structure of the castor bean, its milling technology has developed along lines peculiar to itself. Several special machines have been built to decorticate castor beans. The process depends on cracking the brittle seed coats between rolls set so as to exert a cracking pressure rather than a crushing and mangling one. The beans with their broken seed coats are dropped on a shaking screen which serves to shake the kernels out of the adhering seed coats and otherwise loosen up the mass. As the charge falls over the end of the shaker, a current of air blows out the seed coats, while the kernels fall into a hopper below.

It is very difficult to make a perfect separation of hulls from kernels by the mechanical decortication of castor beans as they are usually delivered from the warehouse. One of the factors contributing to this difficulty is the irregularity in the size of the beans, the small ones dropping between the rolls unaffected, while the large ones are crushed. This requires a grading of the beans, which of course can readily be done mechanically.

Such decortication would be all the better effected if the beans were given a preliminary drying, such as could easily be accomplished in the heaters described later. With regard to the question of added moisture for optimum pressing conditions, see under "Heating." The advantages of decorticating consist in giving a somewhat lighter colored oil and at the same time removing the constituents which wear out the equipment. The literature persistently reports that the Italians produce a very superior medicinal grade of oil, which is practically tasteless, by pressing beans which have been decorticated or dehulled and carefully picked over by hand to remove the bits of adhering hull. On the other hand, the lack of sufficient fiber neces-

sitates in most operations the addition of a so-called binder to prevent the troublesome squirting of the meats from the presses and at the same time prevent the introduction of excessive meal into the oil. The disadvantages so greatly outweigh the advantages that this practice is not followed to any great extent either here or abroad. (See under "Solvent extraction.") A decorticating machine is illustrated in figure 1.

HEATING.

After cleaning, the beans are conducted to the heaters. In contradistinction to other vegetable oleaginous materials, castor

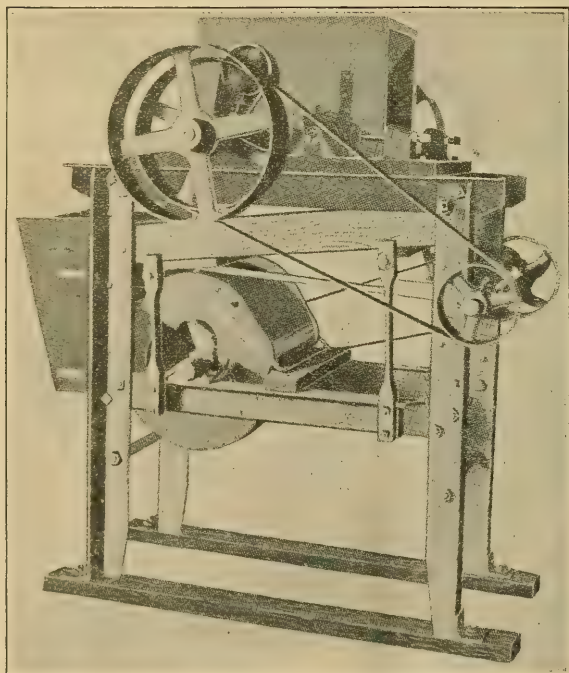


FIG. 1.—A castor-bean decorticator.

beans can not be ground and tempered as can flaxseed, peanuts, soy beans, cottonseed, and copra. The nonfibrous character of the kernel with its attendant high oil content sogums up the equipment that further grinding is difficult. In addition to these technical difficulties, the bean contains a very active lipase or fat-splitting (saponifying) enzym, which very quickly sets free an excessive amount of fatty acid. Accordingly, every effort is made to deliver the beans

to the presses as whole as possible. The reason they are heated at all is to render more mobile the naturally heavy viscous oil. Probably even this would not be done if such treatment served materially to impair the quality of the oil. The temperature to which the beans are raised varies from 100° to 120° F.

To test the effect of heating undamaged beans, a sample from Santo Domingo was heated for 2½ hours at 70° C. (158° F.). It was then carefully picked over to eliminate any black beans, and cold pressed without any further heating in a laboratory cage press at 1,500 pounds applied pressure per square inch. A sample of unheated beans was pressed as a control. In each case the first runnings were discarded

after "wetting" the equipment. The acidity of the oil of the control (unheated) beans was 0.37 per cent, while that of the heated beans was 0.31 per cent, showing no deleterious action due to such heating. The color of the oil in both cases was the same.

A type of heater used in this country for castor beans and known as a grain drier is illustrated in figure 2. This equipment, including the accompanying racks (figs. 3 and 4), is constructed entirely of galvanized steel plates, pressed into the desired shapes and cleated or riveted together in sections, which are assembled and bolted together to build up any desired capacity. The bean-holding compartments consist of a series of vertical racks made up of horizontal steel shelves (pitched bottoms) attached to vertical steel plates. These shelves are staggered opposite each other in such a manner that beans

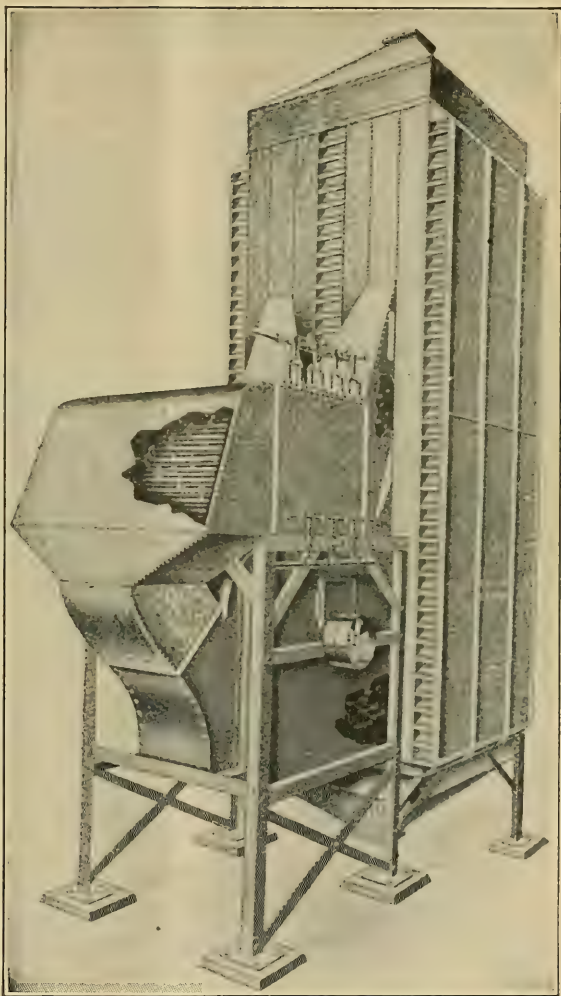


FIG. 2.—A small assembled heater. It is to be noted that the lower cooling section is discarded when used for heating castor beans.

entering the upper end of the racks will descend through a zigzag course between the shelves and from one shelf to another until they are stopped at the bottom by a series of slides operated by rockshafts and levers. They will then pile up vertically without overflowing or leaking from the sides of the racks until the entire height of the racks is again full of beans, forming vertical zigzag layers with both sides entirely open. The beans do not pack in these vertical columns, for the reason that each shelf bears the load of the beans resting directly upon it and the weight is distributed equally throughout

the height of the racks. By adjusting the slides at the bottom, controlled by levers, the discharge may be made continuous or intermittent. Usually the latter practice is followed.

The heating is effected by rising columns of hot air. This air is drawn in by a fan at the bottom and side of the bean-holding equipment and passed over hot closed steam pipes. To prevent the beans from drying out, and also to increase the heating effect of the hot air,

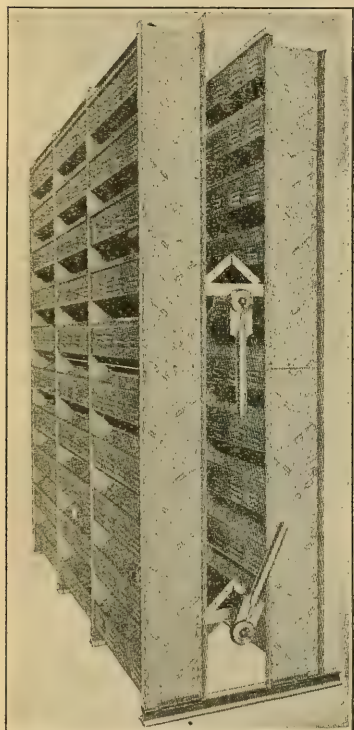


FIG. 3.—Bean racks, showing steel uprights and shelves, saddles, and slide levers. Every surface on which beans are supported is inclined so the beans and dust will flow out when the slides are open, leaving the racks clean. These racks are of smooth galvanized steel and are fitted up closely, without bolts.

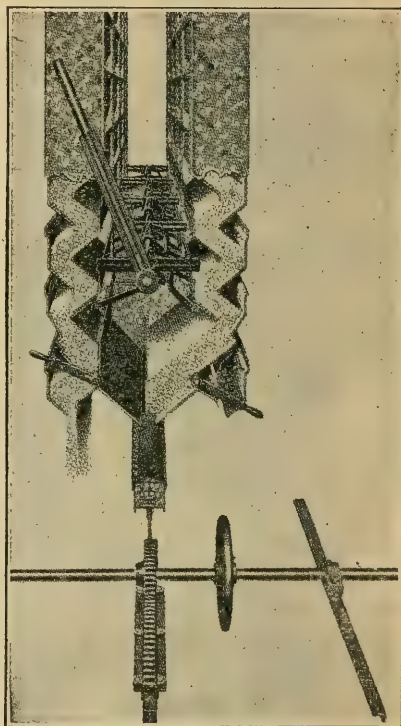


FIG. 4.—Section of bean rack showing it (at the left) discharging at intervals and (at the right) in continuous flow. By throwing the small levers at the bottom of the racks the method of discharge is instantly changed from one to the other. The upper large lever operates the slides for discharge at intervals, but is not used when the beans are flowing continuously.

a jet of live steam is sometimes introduced into the hot-air stream as it emerges from the nests of steam pipes. It is found that an air temperature of about 180° F. will raise that of the beans when delivered to the machines to about 110° F.

Although the above is a method of procedure now followed in commercial practice, it might be well to consider the following facts with regard to improved operation. It is generally conceded in expeller practice that better oil yields are obtained when appreciable quan-

tities of moisture are present. These quantities vary with the character of the material as well as with the way in which the moisture is held, that is, whether or not the moisture is internal and evenly distributed throughout the kernels or oil-bearing particles, on the one hand, or whether, on the other hand, the moisture is distributed over the surfaces of the particles.

To obtain the former condition, the beans are heated in an atmosphere highly charged with moisture in order to prevent drying out, while in the latter case they should be heated in a dry atmosphere with ample facilities for the removal of moisture. In order, then, to add the proper amount of moisture for optimum crushing conditions, a jet of live steam should play into the descending current of material just before it enters the expeller. Such operation has the added advantage of (1) increasing the quantity of oil obtained and (2) securing the economical advantage of using the latent heat of steam to effect the heating of the beans just previous to their delivery to the expellers, thus economizing in the heating operation. Such procedure, of course, gives a dry interior to the oleaginous material and a wet surface.

With further application to improved castor-bean technology, it is evident that this drying effect on the beans would improve and greatly simplify decortication by rendering the seed coats more easily separated from the kernels.

The heaters are located close to the presses in order to prevent loss of heat and to avoid heating the beans for a longer time and to a higher temperature than is absolutely necessary. The lower the temperature to which the beans are subjected and the less the moisture in the oil, the better is the finished product. Heat darkens the oil and moisture increases the acidity.

PRESSING.

In the past, plate presses and cloths were used for castor-bean crushing. On account, however, of the nonfibrous character of the beans with their attendant property of "creeping" under pressure, the cloths would break and the meats would squeeze out. When castor beans are crushed in such hydraulic presses to give a cold-drawn oil, it is stated that a yield of about 17 pounds of oil to the bushel is obtained. Regrinding the cake and heating to 180° to 200° F. for a second pressing yields an additional 3 pounds of oil, leaving about 5.5 per cent of oil in the cake. These figures probably refer to the 46-pound bushel, but the quality of the oil is not up to that from cage presses or expellers. Pressures great enough to yield 17 pounds of No. 1 oil per 46-pound bushel are liable to introduce objectionable impurities. However, with pressure sufficient to yield 16 pounds of No. 1 oil, this oil need not be discounted.

This method has been abandoned for that of the cage press. Essentially this latter is an ordinary hydraulic plate press with the plates removed to accommodate an iron box (or cage) with rectangular or cylindrical cross section, open at both ends, and with the walls perforated over their entire surface. This cage is set vertically in the press in place of the removed plates, while the ram head just fits the cage and rises into it. A headblock above the cage and attached to the press frame likewise fits into the cage from above and supplies the resistance against which the ram operates. Other cages consist of vertical bars set closely and clamped by heavy rings to resist the bursting pressures.

The method of filling the cages varies with different types of presses. Some cages are filled on a so-called charging press and are transferred with their contents to the finishing presses, while others press in only one operation. In any case, when charging, the cages remain in position in the press frame with the ram raised to within a short distance of the top of the cage. The cage is filled with beans level with the top and a plate is laid on, closely fitting the walls. Sometimes a mat is laid on the plate. The ram with its charge then descends a given distance, leaving a space equal to the first one. This is filled level with beans and another plate added. The process is continued until the ram has been lowered to the bottom of the cage, leaving the latter filled with layers of beans separated at given distances by plates. The number of such plates may vary from 6 to 50. Other types have two horizontal rails in front of the cage whereby the latter can be pulled out from the press frame and either filled from above by dropping in measured quantities of beans separated by plates or discharged of its press cake by dumping below into a hopper or conveyor. The cage is then shoved back within the press frame for pressing.

Whatever preliminary method is used for charging the cage, the subsequent pressing operations are quite similar. The headblock is placed in position so as to engage in the top of the cage. As the ram rises, it compacts the charge of beans and presses it against the headblock, thus developing increasing pressures which cause the oil to start. Maximum yields and a better quality of oil are obtained by so adjusting the rate of rise of the ram that the pressures are developed slowly rather than suddenly or unevenly. Pressures on the ram of 4,000 to 6,000 pounds per square inch are now in operation, and some foreign mills are being built to apply 8,000 pounds to the square inch. The duration of the operation varies from 15 minutes to 1 hour, depending on whether a large tonnage of beans is being handled with a higher content of oil in the cake or a less tonnage with a correspondingly greater yield of oil per bushel of beans. Typical cage presses are illustrated in figures 5 to 10.

In figure 5 the press at the right shows the overhead plunger rolled back and the cage ready to receive the crushed material; the press at the left shows the plunger in position to receive the pressure. During the pressing operation metal shields are placed around the

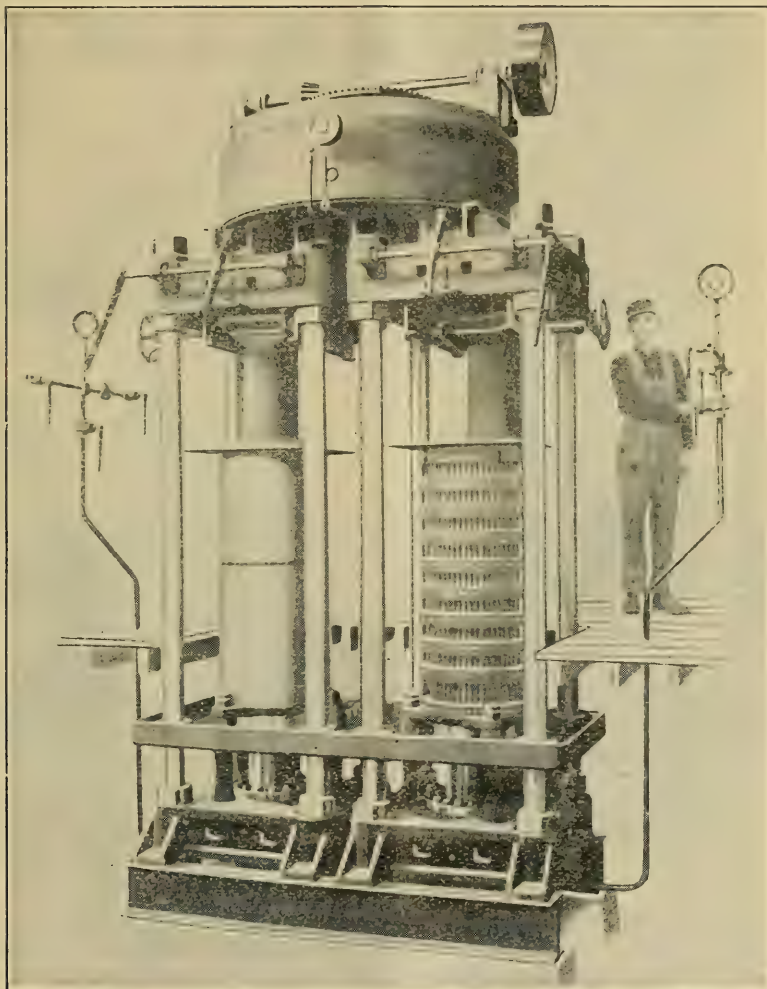


FIG. 5.—A cage press inclosed in a shield (at left) to prevent the squirting of the oil. Overhead plunger rolled back to permit filling the cage (at right).

retaining cages for the purpose of preventing the oil from squirting and to conduct it to the pan below.

Figure 6 shows an ordinary plate press which has been converted into a cage press by removing the plates and substituting a small specially constructed cage to fit within the press frame, holding about 1 bushel to the charge. A frame has been added in front of the cage, on which to slide out the latter for filling and dumping.

Figure 7 shows a filling press, the object of its use being to fill a cage, tamp the contents, and thus conserve pressing space in the operations which follow. Otherwise, the initial shrinkage of the batch due to the application of high pressure would result in much loss of valuable pressing space. Figure 8 shows a discharging apparatus used in removing the cakes from the press, a comparatively slow operation, the object of its use being to avoid diverting heavy pressures from their intended use. Figure 9 shows a finishing press for the heavy pressure for the production of oil. Figure 10 shows a filling, finishing, and discharging press, where all operations are

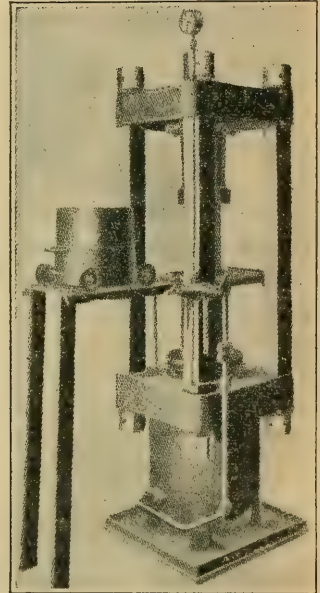
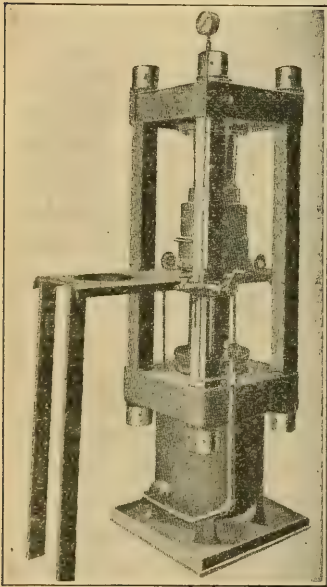


FIG. 6.—A cottonseed plate press converted into a cage press. Cage under ram, ready to receive pressure, at left; press, showing cage out ready to be charged, at right.

performed in the same press. Figure 11 shows a carriage with the cage used in transporting a cage between the various presses.

After pressing, the cakes are removed from the retaining cages by rolling back the overhead plungers and applying the pressure. The cages are bolted in a stationary position to the press pan and the press ram works up through the cage, forcing the pressed cakes out at the top, from which point they are removed by the operator.

Castor-bean cake is very different from that of other oilseeds. In the latter, the cakes are as firm and low in oil as any produced in plate presses. In fact, the newer developments of cage presses are producing cakes lower in oil than those obtained by any other pressing operation. In the case of castor beans, however, the cakes are not cohesive and dry, but readily crumble and fall to pieces.

Usually they contain from 12 to 20 per cent of oil, according to the length of the pressing cycle and the pressure applied. These high percentages of oil in the cakes are caused by the presence of the seed coats, which form little cups throughout the mass and prevent ready draining of the oil and crushing of the kernels. So incomplete is the crushing that the kernels often retain their original shape. On the other hand, it has been stated that the application of too great a pressure produces oil which precipitates an albuminlike product on standing. Thus, like most commercial operations, there

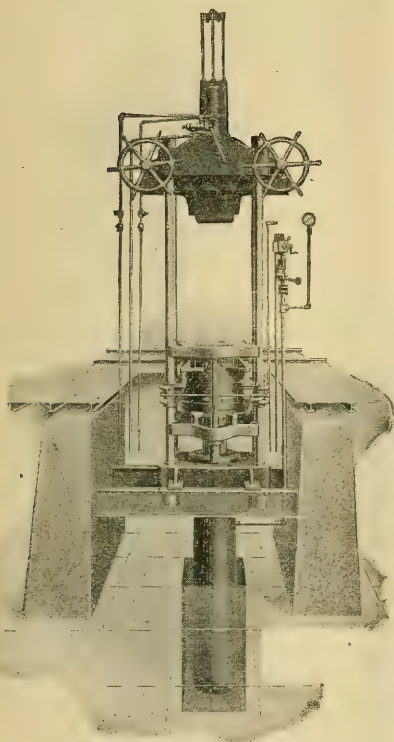


FIG. 7.—A cage filling press.

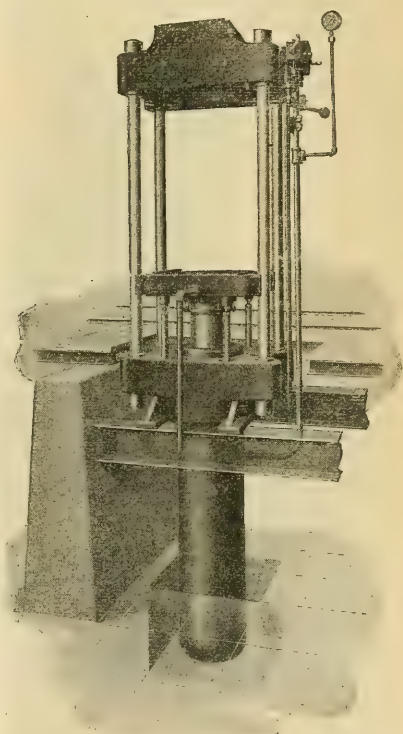


FIG. 8.—A cage discharging press, used to remove the cakes.

comes a point where a satisfactory balance is struck between quantity and quality, beyond which the operator sacrifices profits. Good practice yields about 15.6 pounds of No. 1 cold-pressed oil to the bushel of beans, with 4.3 pounds remaining in the cake as No. 3 oil, assuming 46 pounds of beans to the bushel and an oil content of 45 per cent. Such large percentages of oil in the cake, together with the high prices of the oil, warrant treatment of the cake for the recovery of this oil. This, of course, can be accomplished only by solvent extraction.

These cage or curb presses are made in various sizes, with capacities varying from 100 pounds of beans per hour to about 1 ton. The curbs correspondingly vary in diameter from 10 to 19 inches and in height from 2½ to 9 feet. An actual installation of such equipment consists of a heating kettle provided with a steam jacket and stirrer immediately over the press, so that the heated contents of the kettle can be discharged through an opening in the bottom directly into the cage. These beans are heated to about 90° F. and pressed to the desired degree. The resulting cakes contain only about 10 per

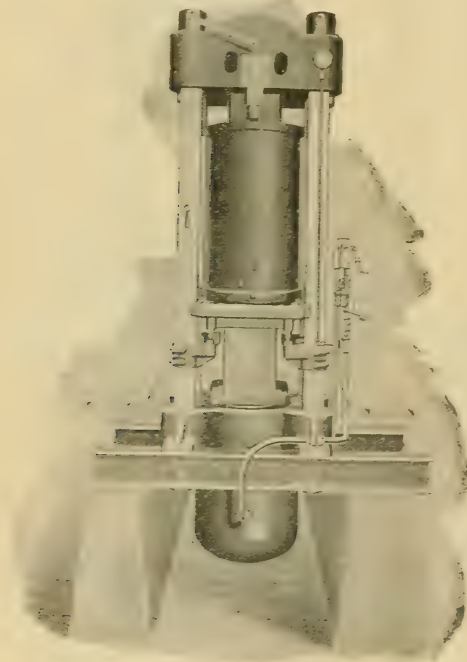


FIG. 9.—A cage finishing press for the heavy pressure necessary for the production of oil.

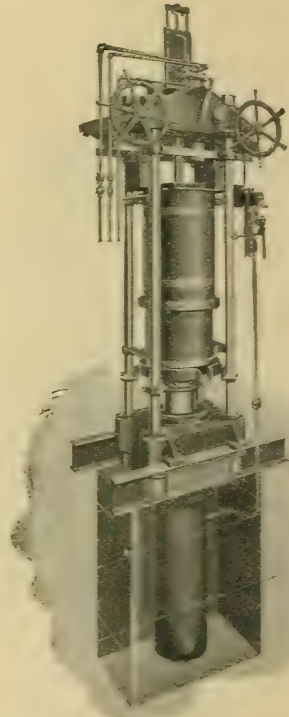


FIG. 10.—A cage filling, finishing, and discharging press, where all operations are performed in the same press.

cent of oil. Four such presses operated by two men have capacities of 500 pounds at each pressing, or an hourly total of 2 tons for the four presses with two pressings; 3 tons with three pressings per hour.

EXPPELLING.

The other method used in modern oilseed milling which has been applied to castor-bean pressing is that of expelling the oil in Anderson oil expellers. These machines are built around a horizontal cage or barrel, about 6 inches inside diameter and 33 inches long, which consists of bars about 0.025 inch apart at the feed end, 0.015 inch

at the middle, and 0.025 inch at the discharge end, all bound together by massive clamping bars. A horizontal screw rotating on the axis of the cage carries the charge of oilseed forward and discharges it at the other end of the cage over a cone, which may be moved in or out, according as greater or less pressures are sought. The charge of oil-bearing material is introduced through a hopper into the cage or barrel and the slowly rotating worm engages it and carries it forward. As the charge reaches the small aperture around the cone it encounters more resistance, which operates to build up pressures within the barrel. These pressures are regulated by varying the size of the aperture between the cone and the walls of the barrel. The farther the cone is moved into the barrel, the smaller is the aperture through which the cake may be discharged. Inasmuch as the screw moves forward at a constant rate and thus delivers a continuous quantity of material to the barrel, it follows that the oil yield is readily controlled by simply adjusting the cone and varying the size of the discharging aperture. For ordinary materials these expellers can be adjusted to yield cakes containing as low as 5.5 per cent of oil.

These machines are very generally used for peanut and copra crush-

ing and for many other oleaginous materials, all of which, however, must have such fiber content as to present sufficiently effective binding properties to prevent squirting of the meats through the interstices of the bars. There is, of course, great wear of the parts, but since these are standardized they can readily be supplied. It has been stated that with properly cleaned material and with right care of the machine the upkeep is no greater than the cost of the cloth in plate presses. An average for more than seven prewar years shows the upkeep to have been about \$100 for each machine per annum.

Figure 12 represents a battery of such machines set up somewhat as they appear in good factory installation. Manifestly, the small labor charge attendant on their operation is much in their favor, together with the cleanliness and mechanical simplicity of their action. One man can operate the whole battery, and even more.

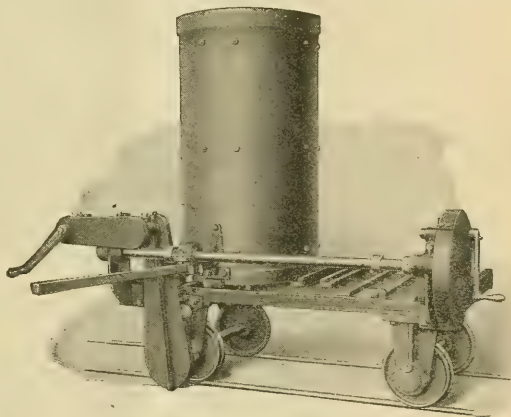


FIG. 11.—A cage carriage.

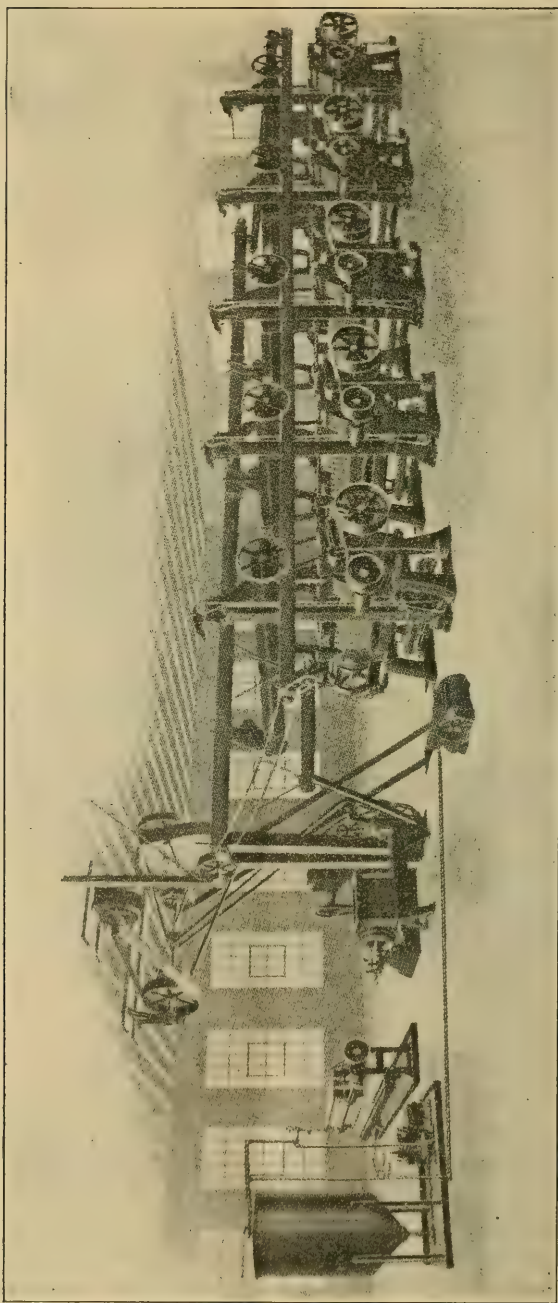


FIG. 12.—Battery of expellers, with pump, filter press, and oil tank.

Expellers for castor beans should be designed similar to those used for copra; other types are not as satisfactory. Such machines have three worm flights on the pressing screw, whereas those intended for crushing other more fibrous and lower oil-bearing materials have only two flights.

Castor beans being low in fiber can not readily be handled in the expellers when excessive pressures are applied, owing to the large quantity of meal which accompanies the oil. If subsidiary equipment is used for removing the meal, this objection is minimized. However, inasmuch as such high pressures are accompanied with the generation of appreciable quantities of heat, which serve to darken the oil, and also since the cake is to be extracted for the residual oil, the market for which is only very slightly below that of pressed oil, good practice applies comparatively little pressure, which results in the production of a cake about seven-sixteenths of an inch thick containing about the same amount of oil as that produced by cage presses, namely, 12 to 15 per cent.

Because of the necessity for some binder to hold the cake within the machine and to preclude the squirting of the meal, it is impracticable to decorticate castor beans. However, if decortication is desired for any purpose, the necessary binder can be mixed with the kernels to hold them and to form a cake. To test this method, decorticated castor beans were mixed with 9 per cent of peanut hulls and expelled as usual. The resultant cake came out in very good form, and the oil was quite free from meal. Since decortication reduced the tonnage pressed by 35 per cent and the added fiber was only 9 per cent, it follows that a net reduction in tonnage of about 26 per cent was effected, resulting in approximately one-third greater expelling capacity.

The unsatisfactory results accompanying earlier attempts to apply the expeller to castor-bean oil manufacture are not hard to understand. The wearing parts of the expellers made 15 years ago were of cast steel and consequently were quite susceptible to the abrasive action of the hard siliceous seed coats. Since then, however, the wearing parts are of case-hardened steel, which presents an altogether different aspect to the abrasive action. The Government castor-oil mill at Gainesville, Fla., has an installation of 15 expellers which have been operating for several months and yet show actually less wear than is observed when used for expelling peanuts. Out of a possible linear movement of $2\frac{1}{2}$ inches in which the cones can be moved to take up the wear, they have been taken up only half an inch.

A test batch of 1,701 pounds (37 bushels) of castor beans heated to 140° F. was expelled in a regularly installed factory expeller. The operation required 2.27 hours and yielded 727 pounds of oil and 920 pounds of cake. Based on the 46-pound bushel, this is equivalent to

2.46 gallons (19.7 pounds) of No. 1 oil, containing about 10 per cent of meal. The beans assayed 48.4 per cent oil. Inasmuch as there is normally about 2 per cent of trash with an additional loss of about 1 pound per bushel for shrinkage, it follows that the oil content of the cake was about 11.6 per cent. The No. 1 oil was agitated with 5 per cent fuller's earth and 2 per cent fitchar at 85° to 90° C. for 10 minutes, then for 15 minutes at 70° to 85° C., and filtered. A very light colored oil was obtained. The above pressure was too great, however, for satisfactory mill operation.

Messrs. Pinnock and Goetz, of the Bureau of Aircraft Production, expelled the oil from a batch of beans in the hull in order to test the possibility of obviating the expense of maintaining hulling stations scattered over the country, and also of assembling in one place all merchantable castor-bean products. By such practice all hulls are included in the residual pomace as fertilizer, the costs of hulling and attendant contractor commissions are eliminated, shipping costs are reduced by eliminating bagging, while an oil of lower acidity is obtained, owing to the protection of the brittle seed coats from cracking during handling. The great disadvantage, however, is that a green-colored oil is produced. For lubricating purposes this is of little moment, but in ordinary trade it is unacceptable. However, the oil can readily be bleached by refining it first with alkali and then bleaching with fuller's earth and carbon. From 258½ pounds of beans in the hull, 79¾ pounds of oil and 166¾ pounds of cake were obtained. Since the original oil content of the beans was 34.5 per cent, it follows that the operation yielded about 92.75 per cent of the total oil. No oil was lost by absorption in the extra cake, owing to the fact that the hulls themselves contained 6.4 per cent of oil.

Unless proper care and skill are applied in using the expellers the machines produce an oil high in meal. To prevent this, it is necessary that the proper amount of moisture be present, and that the beans be heated. On starting a cold expeller, a thick mass of meal and oil is produced, but after running about half an hour the machine warms up and produces an oil with apparently no more meal than that from a hydraulic cage press. In a day's run of seven hours there is produced only about 1 quart of such meal by each machine. Oil made in expellers is certainly heated to higher temperatures than obtain in cage pressing. As it drips through the bars it has an average temperature of about 176° F., while that of the cake as it emerges at the discharge is about 133° F. So little deleterious effect is produced on the oil by this heat that it must be attributed to the extremely short duration of the exposure.

The expellers in the Gainesville plant have been regularly operating on 800 pounds, or about 17 to 18 bushels of beans an hour, but under forcing can do materially more. A test on an experimental

expeller indicated a possible thousand pounds, or an hourly rate of 21 bushels. In the expeller plant at Gainesville, the machines were not set to yield more than about 15 pounds of oil per 46-pound bushel.

The relative quality of expeller castor oil compared with that of hydraulic pressed oil will be considered later.

SOLVENT EXTRACTION.

On account of the large proportion of residual castor oil left in the cake from the pressing or expelling operation, namely, from 12 to 20 per cent, or about 5 pounds per 46-pound bushel, solvent extraction of the cake is universally practiced in this country, following the methods generally applicable to oleaginous products. The units comprising a complete extraction plant consist of the extractor and the solvent-recovery still, the oil-finishing still, the condenser, the solvent and water separator, pumps, and storage tanks.

Two general types of equipment are used, namely, the stationary extractor and the rotary extractor. The former is primarily an English development, while the latter is American, having found extensive application in the extraction of garbage and other waste materials where the great problem is to handle in an economical manner bulky products with small oil content.

The iron stationary extractors vary in dimensions, but may have a diameter of 6 to 8 feet and a height of 10 to 12 feet, entirely inclosed, with, however, apertures for loading and discharging and also stirrers and vapor pipes. The extractor is provided with a false bottom, perforated over its entire surface with small openings, varying in size with the character of the material to be extracted. These openings may be over an inch in diameter, but if finer materials are to be extracted auxiliary plates with smaller perforations may be laid on.

In order to obviate channeling in castor-pomace extraction, attempts have been made to operate a stirrer, but owing to the tendency of such material to pack during extraction it has been found impracticable to operate such stirrers when the extractors are charged to anything like their capacity. Accordingly, recourse is had to auxiliary methods of breaking up channeling in extraction, as well as in "steaming off" the solvent in the final treatment. Another difficulty of stationary extractors is that there is a tendency for materials containing large quantities of nonfibrous albuminous material to pack on the bottom, which very effectively precludes the circulation of the solvent, so essential to the efficiency of extraction. Among the methods which have been used to obviate this packing tendency of castor beans is that of laying burlap between quarter-inch chicken wire over the floor, spreading

thereon a layer of hulls, and then piling the pomace on this. Such an arrangement in conjunction with the introduction of the solvent from below insures the movement upward rather than downward of the albuminous products and other sedimentation and greatly minimizes the tendency to pack. Such an extractor may hold a charge of 10 tons with a period of operation of possibly 20 hours from the commencement of loading of one batch to that of the following batch.

The advantage of the stationary type of extractor is simplicity of installation and absence of more or less complicated machinery.

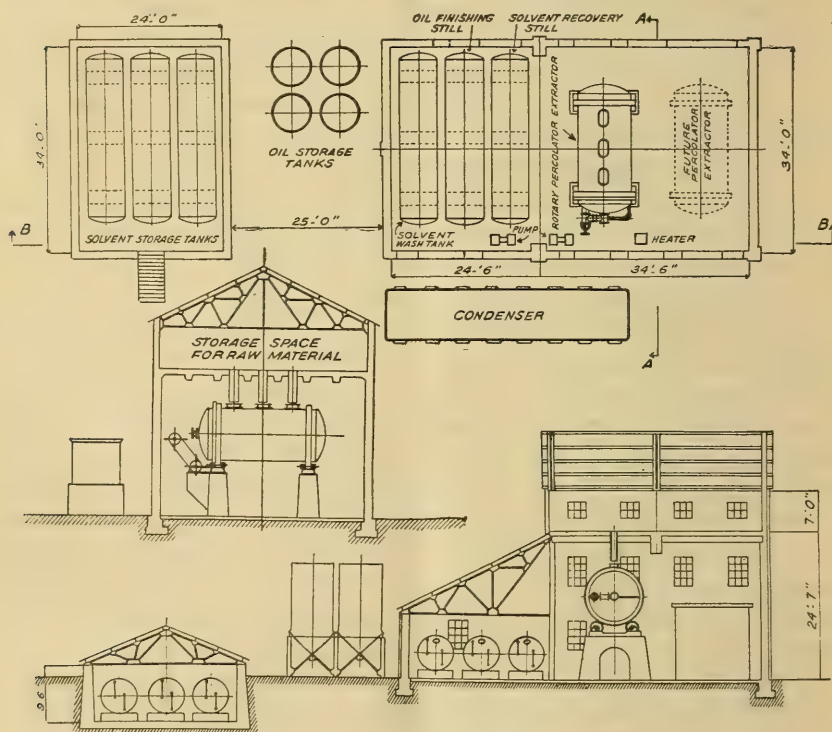


Fig. 13.—Sections of extraction plant.

The rotary extractor is finding increasing favor because of its ease of operation, efficiency of performance, and low labor charge. The central unit of the rotary extractor plant (fig. 13) consists essentially of a closed cylindrical tank, mounted horizontally upon riding rings and provided with a series of manholes along one side for the introduction and discharge of material. This tank is mounted upon trunnion rollers and is rotated by means of a girt gear which is attached to one end of the shell and driven by a set of geared countershafts. A false bottom covered with burlap extends along the entire length of the tank, thus leaving a clear flow for the

solution of oil in the solvent. Such extractors are made in various sizes and may be from 5 to 8 feet in diameter and from 12 to 18 feet long. The solvent and steam are introduced through openings in the top; the saturated solvent and steam are drawn off at the bottom. Another type introduces steam and solvent through a journal bearing in the axis at one side and discharges steam and saturated solvent through a similar opening in the axis on the other side, first passing through a perforated false head which divides the discharge end of the tank, into a small compartment into which the filtered solvent collects. The smallest of such units will hold about 3 tons of oleaginous material to the charge, while the large ones may hold as much as 6 tons. The total period of treatment from the time of the commencement of loading back to the corresponding stage of the succeeding batch may be about 12 hours, enabling the units to be used twice in 24 hours. The channeling of the batch is obviated by rotating the tank at intervals, thus breaking up pockets and other deterrents of good extraction.

With the exception of the form of the extractor, the rest of the solvent plant is quite standard and simple. The solvent-recovery still may be provided with a steam jacket on the bottom with auxiliary heating coils, or with a calandria somewhat similar to that used with sugar pans (simulating an upright fire-tube boiler) where steam circulates on the outside of the tubes while the evaporating charge boils up inside the tubes and down wider openings provided for the purpose. An open steam coil is also provided in the bottom of the still for blowing off final traces of solvent at the end of the operation.

The oil-finishing still is very similar in construction to the solvent-recovery still, and where such installation is made its purpose is to complete the operation of removing the solvent left unfinished in the preceding solvent-recovery unit. Where the latter is used for the preliminary separation of oil and solvent, these stills, particularly the oil-finishing still, should be equipped for operating under vacuum.

The solvent and water separator is usually a tank with a separate compartment and overflow for drawing off the water which has settled from the distilled mixture of solvent and water. Such separation must be effected in a quiescent condition, because even a slight agitation of the layers precludes quantitative recovery. It may be necessary to install a preliminary water-solvent separator to take up the pumping pulsations in order to obviate the churning effect when the vapors and condensed liquor are discharged direct from the vacuum pump during any part of the boiling-off operation.

The other equipment of such a plant consists of storage tanks for saturated solvent and oil, for solvent alone, and for oil; also a solvent heater, boilers, and conveyors. All storage tanks should be pro-

vided with indicators to record the level of the contents, or when buried under ground with indicators above ground to register the contents.

Heretofore there has not been much inducement for manufacturers to prepare a high-grade No. 3 oil. Consequently, the generally recognized darkening effect of heat due to steaming off has not been considered. If, however, effort is made to produce a high-grade oil with a minimum of color, care must be exercised not to expose the oil in the solvent-recovery still or oil-finishing still to this high temperature.

By such solvent extraction, as generally practiced, a pomace is produced running from 10 to 12 per cent of moisture and containing anywhere from 0.6 to 2 per cent of oil. This low content of oil can be attained only by very efficient extraction, determined by the kind of solvent used, the number and efficiency of the washings, and the type of equipment.

SOLVENT-EXTRACTED NO. 1 OIL.

In the course of the work of this laboratory on the technology of castor-oil manufacture, evidence has been obtained which indicates that a very promising oil of apparently No. 1 grade can be made entirely by the solvent process. Without decorticating the beans, they were slightly crushed in order to break the seed coats and extracted with benzol by percolation. The solvent saturated with oil was of a characteristic light-green color, similar to oil always produced by such extraction. The benzol was evaporated at atmospheric pressure until toward the end of the distillation, whereupon a vacuum was applied. The residual oil with greenish yellow color was then heated to 95° to 110° C. at atmospheric pressure and treated with 5 per cent of fuller's earth with constant agitation for about 10 minutes, whereupon 2 per cent of decolorizing carbon was added and the stirring continued, while the temperature was allowed to fall slowly to about 90° C. At the expiration of about 15 minutes the oil was filtered and came through with a light straw color. Inasmuch as every castor-oil expelling plant must have an auxiliary extraction equipment, it follows that if a satisfactory grade of oil, colorless and low in acidity, can be made by such means it will materially reduce the cost of production.

TREATMENT OF POMACE.

The dry, more or less dusty pomace from the extraction house is conveyed to the pomace warehouse. If it is lumpy, it is passed through a grinding machine, which may be of the rotating-disk type, spiked-roller (crusher), or swinging-hammer type, where it is pulverized. If the moisture runs above 12 per cent, decomposition may set in, resulting in an appreciable loss of ammonia, the only constituent of real commercial value.

FINISHING THE OIL.

REFINING.

Various methods are recorded in the literature for refining castor oil. Among these may be mentioned acid refining by sulphuric acid, settling of the foots, and subsequent washing out of the acid. Other methods involve refining in alcoholic solution. As far as can be ascertained, these methods are not generally applied. British practice has long consisted in passing live steam into the oil, which serves to coagulate and precipitate the albuminlike constituents, which are filtered off. That this product is nitrogenous has been demonstrated. The oils listed in Table VII were analyzed for nitrogen.

TABLE VII.—*Analyses of castor-bean oils of diverse origin, showing nitrogen content.*

Source.	Nitrogen ($N \times 6.25$) content (per cent).	
	Raw.	Treated.
American.....	{ 0.0159 } 0.0164 { 0.0163 } 0.0163	{ 0.0163 }
Newchwang.....	{ .0399 } .0434 { .0175 } .0182	{ .0183 }
"Chinese".....	{ .0338 } .0350 { .0163 } .0173	{ .0183 }

Castor oil can not be freed from acid as readily as some of the other staple oils, such as cottonseed and peanut oils. Instead of the soaps breaking readily and settling out, the castor-oil soaps only partly do so but have a tendency also to dissolve in the oil, rendering the latter very viscous and thick. Consequently, the oil has to be very thoroughly washed to remove such.

No. 1 castor oil is usually so low in acid that it serves all industrial purposes without refining. However, there are times when the oil may run high in acid, on account of the character of the beans received at a given plant, or the acidity may run up, owing to factory troubles. All No. 3 oil is high in acidity, with a range of possibly 5 to 7 per cent figured as oleic acid. All such oil can be refined as follows:

The oil should first be heated to about 85° C. and treated with caustic-soda solution approximately 16° Baumé. With the temperature maintained at this point the oil and alkali are agitated gently to insure intimate contact, whereupon agitation is withdrawn and the aqueous soapy layer allowed to separate as much as it will. It is then drawn off. The oil is then heated to around 95° C. and sprayed with successive portions of boiling-hot water (preferably brine) with thorough agitation. Agitation that is too violent produces a troublesome emulsion, which can only be broken with difficulty and by long heating or sweating out. If, however, the hot oil is given comparatively mild agitation over the layer of hot water which has settled to the bot-

tom, with just enough motion to insure good movement between the two phases without emulsifying them, it is found that all soap can readily be removed. If an emulsion should form, it can be broken by heating the oil and sprinkling in salt, with such agitation as has been described. Upon the settling out of the brine, it is drawn off and the oil dried and filtered.

No bleaching has been effective for the regular commercial types of No. 3 castor oil. This is attributed to the fact that the present practice has fixed the color by overheating and at the same time has introduced iron salts, due to the action of the comparatively high acidity upon the container walls. It has been found that castor oil, though highly colored, can be refined by alkali treatment and bleaching only when the oil has been treated with the same care that applies to any other oils intended for bleaching. A greenish yellow extracted oil has been successfully bleached, as well as a green oil produced by expelling castor beans in their original hulls or pods, but no success has been attained in endeavoring to bleach any of the commercial types of No. 3 oil, whether green or brownish yellow.

BLEACHING.

Castor oil coming directly from the presses or expellers is of a brownish gray color, due to suspended meal and droplets of water. Inasmuch as the oil produced by cold pressing or expelling runs low enough in acid to be satisfactory for the general purposes for which No. 1 castor oil is intended, it is not refined in practice, but merely cleaned up and bleached. Before satisfactory filtering and bleaching can be accomplished the oil must be dried. This is effected by heating the oil either at atmospheric pressure or in vacuum. Such equipment consists of an oil tank with closed coils, agitator, sight glasses, and a small 4-inch entrainment, which seems small but is ample to carry off the comparatively small amounts of water. Closed steam coils supply the necessary heat. Effective agitation is necessary to bring the moisture-bearing portions to the surface for ready drying. The oil may be circulated by pumping from the bottom and in at the top in the form of a spray, which, of course, operates to minimize the period of heating. After such drying is effected the oil is pumped to a mixing kettle and treated with fuller's earth and carbon. The practice differs in different plants and according to the grade of the oil. A common method is to heat the oil to approximately 200° F., preferably in vacuum, and then add from 2 to 4 per cent of a good grade of dry fuller's earth. This mass is agitated for half an hour and then a good grade of bleaching carbon is introduced, varying from 0.2 to possibly 1.5 per cent, according to the grade of oil and quality of product desired. The oil is filtered and is then ready for market.

A centrifugal machine (fig. 14) has been devised departing in some respects from the ordinary basket or cone centrifuge, which has been found quite satisfactory on a laboratory scale for removing from the oil large quantities of the sticky albuminlike product which on long standing settles from oils and which so seriously impairs the capacity of the filter press. This machine by removing such meal and other substances as are difficult to filter out leaves an oil with only a thin cloud, but which can be treated with fuller's earth, bleached, and filtered with much greater ease than with the bulky precipitate retained. The walls of this centrifuge are solid and not perforated, as in the laundry type. A series of baffles (fig. 15) attached alternately to the wall and to the central shaft forces the oil to take a deviating course through the centrifuge, resulting in the collection of the precipitate in the lower portions of the centrifuge somewhat similar to the throwing out of moisture from steam

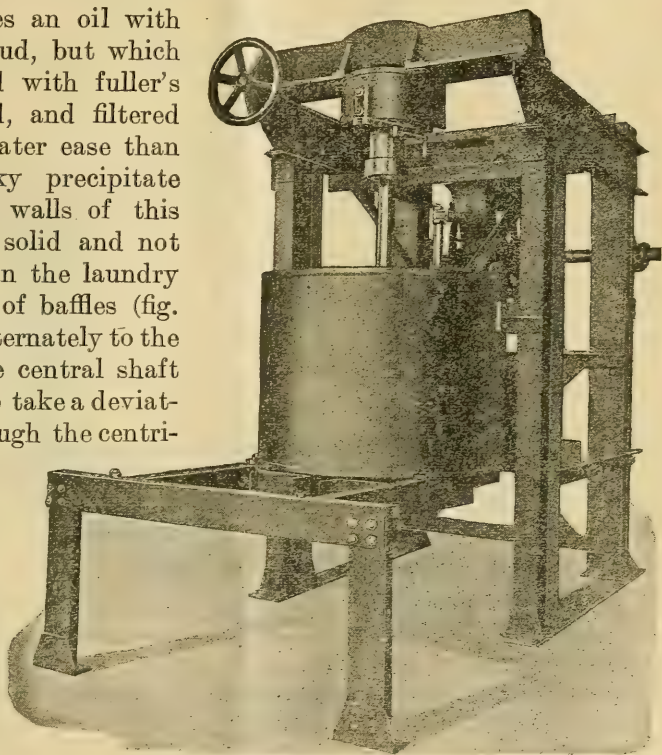


FIG. 14.—A centrifugal separator.

when the latter passes through the trap or catchall in a vacuum entrainment. (Fig. 11.)

The hot oil with its charge of fuller's earth and carbon is then pumped through an ordinary plate-and-frame filter press, the cloths of which should be covered with paper in order to obviate the trouble and difficulty of washing out the adhering earth from the pores after each filtration. All that is necessary in this case is to wash the cloths with alkali after several runs in order to remove the oil without the attendant rubbing necessary to clean up the pores. The filter papers with their charges of earth and carbon can be lifted off the cloths and thrown into the solvent extractors, thus greatly

minimizing the labor of cleaning up the press. As is usual in such operations, the oil must be pumped through the filter press and back into the original mixing tank for half an hour or so in order to coat the leaves with a layer of earth, owing to the fact that the first runnings of oil are cloudy and clear up only when the plates are well covered. The stream of clear oil should then be pumped through a

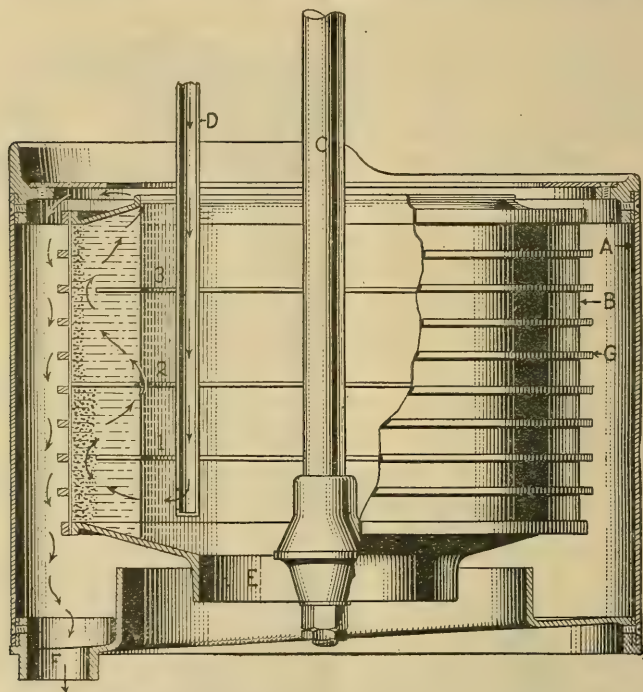


FIG. 15.—Sketch showing details of construction of the centrifugal separator shown in figure 14.

second press in order to catch any fine specks which may escape the first filtration.

Such treatment should produce a very light oil, no darker than a fine straw color. However, low-quality beans and faulty factory practice may result in greater color and unreasonable acidity. Factors contributing to high acidity are moisture and heat, particularly the former, while those affecting color are largely heat, particularly when the oil is heated in contact with seed coats or hulls. A clear bleached oil heated for a little over half an hour at 195° F. materially darkens, but samples of oil heated for one hour at 400° F. suffered practically no change in acidity. This refers to both No. 1 oil and refined No. 3 oil. The acidity of the oil does not materially increase during the several days which elapse between manufacture and finishing. Under common practice the oil from the first day's run is collected at the end of the day for weighing. It is then dried over

part of the following day and the third day is finished by bleaching and filtering. During this time the increase in the acidity is almost negligible, increasing only about 0.1 of 1 per cent. An oil can hold 0.15 per cent moisture without clouding, but when the moisture runs up to as much as 1 per cent the moisture settles out and a permanent cloud is formed.

PROPERTIES OF THE OIL.

The quality of castor oil is determined in the trade by its color, clearness, and acidity. The best grade, designated as No. 1, is a cold-pressed oil low in acidity, brilliantly clear, and approaching colorlessness. Some cold-pressed oils are a very light straw color, almost white; all hot-pressed oils are brownish yellow, while the so-called No. 3 grade varies from dark brown to green. There is no generally recognized No. 2 grade, since this was designated by only a few dealers to represent some stock inferior to No. 1, but better than No. 3. The specifications accompanying trade in this commodity usually consist of clearness, color, acidity, specific gravity, iodine value, saponification value, odor, and taste.

TABLE VIII.—Analyses of commercial samples of castor oil covering the period from November, 1917, to December, 1918, and of expeller oils made at the Government plant at Gainesville, Fla., in the spring of 1919.

Properties compared.	Hydraulic-pressed oil.		Expeller oil (series of more than 100 samples).	
	Range.	Average.	Range.	Average.
1	2	3	4	5
Specific gravity (15.6° C.)	0.961 to 0.965	0.9626	0.9610 to 0.9634	0.9620
Acidity per cent.	^a 0.45 to 1.6	1.22	0.60 to 1.83	.98
Iodine number	83.0 to 87.5	85.6	^b 82.7	.....
Saponification number	176.3 to 188	182.5	^b 181.4	.....
Unsaponifiable matter per cent.	0.21 to 0.78	.33	.....	.....
Flash point ° F.	513 to 570	535	.....	.....
Viscosity	^a 93 to 112	97.1	.....	.....

Properties compared.	Expeller oil (series of 7 samples).		Extracted oil.	
	Range.	Average.	Range.	Average.
1	6	7	8	9
Specific gravity (15.6° C.)	0.961 to 0.962	0.9613	0.9607 to 0.9624	0.9614
Acidity per cent.	0.85 to 1.46	1.17	^a 3.09 to 6.66	4.80
Iodine number	80.8 to 86.1	84.2	.....	.....
Saponification number	178 to 182	179.6	.....	.....
Unsaponifiable matter per cent.	0.20 to 0.30	.26	.....	.....
Flash point ° F.	524 to 527	525	.....	.....
Viscosity .....	.....	.....	.....	.....

^a One higher value in each case was discarded as unrepresentative.

^b One sample.

An average of 54 analyses of commercial samples of No. 1 castor oil manufactured by the leading crushers, covering the period from November, 1917, to December, 1918, is given in Table VIII, columns 2 and 3. These hydraulic-pressed oils are from cage presses and represent the normal product regularly made. In columns 4 to 7 similar data are given for expeller oils made at the Government plant at Gainesville, Fla., including more than 100 samples manufactured during the spring of 1919, and in columns 8 and 9 are given the specific gravity and acidity of samples of extracted oil.

That the refining of castor oil does not materially alter its chemical characteristics other than merely to remove the acid is shown in Table IX. Sample A represents a refined No. 1 oil the acidity of which had risen to 10 per cent, while sample B is from a batch of No. 3 oil chemically refined.

TABLE IX.—Comparison of properties of representative samples of castor oils differing in acidity.

Properties compared.	Sample A.	Sample B.
Specific gravity.....	(At 15.25 B.é. 0.9643.....	(At 15.70 B.é. 0.9613.....
Flash point.....° F.	555.....	555.....
Fire.....do.....	630.....	615.....
Pour test.....do.....	0.....	0.....
Viscosity at 212° F.....seconds..	100 to 101.....	96 to 97.....
Ash.....(1).....	180.85.....	182.48.....
Total saponification.....	Castor.....	Castor.....
Odor.....	Trace.....	Trace.....
Water.....	Light yellow, pale.....	Light green.....
Appearance.....	87.....	91.....
Iodin value.....	O. K.....	O. K.....
Solubility.....		

¹ Trace, considerable alkalinity, but no sulphates. ² Trace, slight trace of alkalinity, but no sulphates.

The following is an analysis of a single sample of No. 1 expeller oil containing properties not determined in the foregoing analyses:

Color.....	Straw, very slight cloud.
Odor.....	Mild.
Specific gravity at 15.6° C. (60° F.)..	0.963 = 15.4° B.é.
Solubility in 90 per cent alcohol....	Completely soluble.
Acid number.....	1.9 = 1 per cent free acid (as oleic).
Iodin number.....	82.7.
Saponification number.....	181.4.
Viscosity.....	98.6.
Unsaponifiable matter (per cent)...	1.0.
Rosin.....	None.
Adulterants.....	None detected.

Samples of castor oil from various sources were heated to 400° F. for 1 hour to ascertain the effect of heating on the acidity. These results are given in Table X, and are reported as the percentage of acidity expressed as oleic.

TABLE X.—Analyses of castor oils from various sources, showing the effect of heating upon acidity.

Description of sample.	Acidity (per cent).	
	Control.	Heated.
Refined No. 1 oil.....	0.47	0.58
C. P. No. 1 oil.....	1.00	1.05
Refined No. 3 oil.....	.71	.79
Refined No. 1 oil.....	.92	.96

It is thus evident that heat alone has little effect on the acidity. This question arose from the possibility that if such acidity did develop, it might operate to pit the walls of the gas-engine combustion chamber during a run.

When the Bureau of Aircraft Production went into the market for castor oil for lubricating purposes it drew up the specifications listed below, giving the properties which a good grade of lubricating castor oil should possess. Since these properties are possessed only by a high-grade No. 1 oil, these specifications may be accepted as fairly representative of this entire grade, regardless of its intended use.

General.—(1) This specification covers the requirements of the Bureau of Aircraft Production in all purchases of castor oil for rotary-engine lubrication. The oil must be a high-grade vegetable castor oil suitable for this purpose. Both cold-pressed vegetable castor oil and hot-pressed vegetable castor oil which has been refined so that it will meet the requirements of this specification may be submitted for purchases. (2) The castor oil must be free from adulteration, other oils, suspended matter, grit, and water. (3) The castor oil must meet the following requirements:

Color.—(4) When observed in a 4-ounce sample bottle, the castor oil must be colorless or nearly so, transparent, and without fluorescence.

Specific gravity.—(5) The castor oil must have a specific gravity of 0.959 to 0.968 at 60° F. (Baumé gravity must be from 16.05 to 14.70 at 60° F.)

Viscosity.—(6) The castor oil when tested in a Saybolt universal viscosimeter must have a viscosity of not less than 450 seconds at 130° F. and 95 seconds at 212° F.

Flash point.—(7) The flash point must not be less than 450° F. in a Cleveland open-cup flash tester.

Pour test.—(8) The castor oil, in a 4-ounce sample bottle one-quarter full, must not congeal on being subjected to a temperature of plus 5° F. for one hour. (See specification No. 3525, "Pour test.")

Evaporation test.—(9) The castor oil must not show a greater loss than five-tenths of 1 per cent when heated in an oven at 230° F. for 1½ hours. This test shall be made on a 5-gram sample in a glass crystallizing dish approximately 2½ inches in diameter and 1½ inches high, inside dimensions.

Ash.—(10) The castor oil shall not show more than 0.015 per cent of ash and shall show no impurity of any sort not related to the original product.

Solubility.—(11) The castor oil must be completely soluble in 4 volumes of 90 per cent alcohol (specific gravity 0.834 at 60° F.). This test shall be made on a 2 c. c. sample.

Acid number.—(12) It must not require more than 3 milligrams of potassium hydroxid (KOH) or 2.14 milligrams of sodium hydroxid (NaOH) to neutralize 1 gram of oil. This is equivalent to 1.5 per cent of oleic acid.

Unsaponifiable matter.—(13) The unsaponifiable matter must not exceed 1 per cent. Samples used for this test shall weigh 5 to 10 grams.

Iodin number (Hanus or Wijs methods).—(14) The iodine number must be between 80 and 90. Samples used for this test shall weigh 0.2 to 0.25 gram and shall be treated for 1 hour.

Rosin (Lieberman-Storch test).—(15) The castor oil must not give a reaction for either rosin or rosin oil.

Cottonseed oil (Halphen test).—(16) The castor oil must not give a reaction for cottonseed oil.

Inasmuch as the chemical analysis does not give the final word regarding the adaptability of an oil for lubricating purposes, engine tests have been made on the lubricating value of No. 1 hydraulic-pressed oil, No. 1 expeller oil, and No. 3 refined oil. The results of such tests show these oils to be of equal value for lubricating purposes. Since the chemical and physical constants expressed above are practically identical, it follows that color is the only evident means of differentiating between the various oils. A demulsibility test applied to hydraulic-pressed oil compared with expeller oil reacted slightly in favor of the expeller oil. The difference, however, was so slight that the two oils may be considered in this respect practically identical.

The following statements quoted from leading dealers in castor oil (not manufacturers) show how the trade considers American-produced oil as compared with various imported stocks:

The American-pressed castor oil will remain free from rancidity for a longer period than the imported oils and as a general average is vastly superior to any imported oil that we have received.

The oil that comes from China and the Far East seems to be of a decided yellow color and, in the writer's judgment, would indicate that it is hot pressed, i. e., that the oil was pressed from a warm or hot meal.

In our opinion the oil made in the United States is equal, if not superior, to the imported.

We will say that it has happened that the oil we purchased which was made in this country turned out to be better than that we have used which was made abroad.

Domestic-manufactured castor oil will keep longer and be freer from acidity than the oil which is imported. Generally speaking, the imported castor oil, especially from the Orient, contains from 1 to 8 per cent acidity and by keeping the oil the acidity is likely to be increased, especially where the oil tests from 3 or 4 to 8 per cent. We look upon the domestic-manufactured white oil as being best not only for medicinal but for manufacturing purposes.

As a matter of fact, now that the War Trade Board has ruled (January, 1919) that castor beans and castor oil can come freely into this country, we doubt if any of this oil (oriental) will come here. It is, as you may know, an inferior oil, and can only be used in comparison with a domestic production of No. 3 castor oil.

USES OF CASTOR OIL.

Castor oil has properties which serve to differentiate it very markedly from all other vegetable oils. This fact is no doubt attributable to the predominating influence of its characteristic acid radical of ricinoleic acid. The striking properties of this acid are due to the fact that it is a hydroxy acid, a condition which is only approximated in nature in the case of grape-seed oil. This hydroxylated condition is probably the property which serves to render it so valuable in the industries, for it is apparent that when other oils are treated so as to increase their acetyl number and their viscosity they more nearly take on the properties of castor oil. Thus, when an oil is oxidized (blown) it becomes less soluble in gasoline, and its viscosity and acetyl value increase. In fact, the hydroxylation of acids normally soluble in gasoline renders them insoluble in gasoline. Sulphonated oils are insoluble in gasoline. Since hydrolyzing a sulphonated oil is said to yield hydroxylated oils, efforts have accordingly been made in this and other laboratories to produce such an oil, using peanut and cottonseed oils, but without success thus far.

For ordinary lubrication, the viscosity of castor oil is its great asset. Before the application of mineral oils for such purposes castor oil was very largely used as a cylinder oil, but the production of high-grade mineral cylinder oil has greatly displaced it except in the Tropics, where it is still used for lubricating heavy machinery. However, in gas engines, which are lubricated by spraying the lubricant into the cylinder along with the gasoline (notably the rotary air-cooled types), it has been found that castor oil is absolutely necessary. The property of the solubility of mineral oils in gasoline is stated to be the reason that they can not be so used as a lubricant, owing to the lowering of their viscosity and "body" by solution in such a medium.¹ The insolubility of castor oil in such products is given as the cause for its specific advantages in such cases. Some authorities assert that castor oil is preferable to mineral oil because gasoline does not wash it out of the crank case so readily, which is, of course, a corollary of the above. However, mixtures of cylinder mineral oil and castor oil treated so as to maintain their homogeneity are stated after direct trial to be the more satisfactory, although such mixtures are perfectly soluble in gasoline. Castor oil, of course, can be used as a lubricant in other types of motors, but as the supply has been

¹ Although the literature almost universally states that castor oil is insoluble in gasoline, attention is called to the fact that this qualitative statement should be restricted to refer only to conditions obtaining at ordinary temperatures. A gentle heating effects ready solution; in fact, extraction of castor-press cake pomace with gasoline is the industrial method for obtaining the lower grade oil, leaving a pomace with about 2 per cent of oil. In view of the high temperature conditions obtaining in engines lubricated with castor oil, it is apparent that this oil readily dissolves in gasoline; consequently, its specific advantage for lubrication under such conditions would not appear to reside in its insolubility in gasoline but rather to the fact that solution in gasoline leaves it with a viscosity higher than that obtaining with other oils similarly treated.

somewhat limited and at the same time the price materially higher than that of high-grade mineral oil it was found that the latter can be used in ordinary types, while only the former can be used in the rotary types. Abroad, however, castor oil was used almost exclusively in all kinds of aviation motors. The reason given was that castor oil keeps its viscosity better, sticks better, and protects the cylinder walls, valve seats, and other parts. A mixture of mineral and castor oils, containing a preponderating percentage of the latter, has been universally used in stationary motors. Some trouble with foreign castor oil has been due to its tendency to gum, which has been minimized by mixing it with various proportions of heavy mineral oil. Great difficulty has been experienced in forming a homogeneous and suitable mixture of castor and mineral oils, owing to the fact that both are apparently homogeneous at the time of making, but separation occurs upon long standing. A patent has been taken out by Archbutt and Deeley for heating castor oil in an autoclave at 260° to 300° C., under pressure of 4 to 6 atmospheres for about 10 hours, whereby it becomes miscible with mineral oil in any proportion. Some state that castor oil unduly precipitates carbon on the walls of gas-engine cylinders, owing to incomplete combustion, while others claim that because castor oil burns without a smoky flame and gasoline burns with a conspicuous cloud, any carbon deposited on the cylinder walls is derived from the gasoline rather than from the oil.

Some lubricating engineers claim that the high steam pressures occurring in steam cylinders afford ideal conditions for saponifying castor oil, stating that this increases the acidity of the oil, with consequent pitting of the walls. Others claim that the walls remain perfectly bright. Another quality of castor oil as a lubricant, which seems to be quite generally accepted, is its ability to stick to the exposed surfaces, with consequent protection. Castor oil also keeps its viscosity better under changes of temperature than any other vegetable oil and many mineral oils.

Artificial leather is made by dissolving cellulose nitrates in volatile solvents, incorporating castor oil in the mixture and distributing the same over treated cloth. Upon volatilization of the solvent, the solid constituents remain fixed on the goods. The rôle of the oil is to impart softness and elasticity to the otherwise hard and stiff product and to enable this to be more readily coated on the cloth or other backing material. There are very few oils which can be added to nitrocellulose solutions without either causing the separation of the nitrocellulose from the solution or spoiling the luster and cohesion of the film. It is evident that a nondrying oil must be used and also one that is perfectly miscible in the solvents used. Castor oil fulfills these conditions very satisfactorily and is of additional value on

account of its resistance to climatic conditions and temperature changes as well as to its viscosity. A leather substitute, recently patented, is formed of a carrying vehicle, such as paper or a woven fabric, and a facing of supple pyroxylin built up of successive layers united into an integral structure of sufficient thickness to enable it to be removed from the carrier. The coating may be formed of nitro-cellulose 10, castor oil 20, amyl acetate 15, methyl alcohol 20, amyl alcohol 5, benzol 30, and pigment 3 parts. Such leatherlike products come in rolls of 30 to 60 yards in length and of varying widths, and find extensive use in upholstery, carriage tops, automobile fittings, suitcases, trunks, shoes, book bindings, and various lines of novelty goods. It has been generally assumed that only the No. 1 grade of castor oil is satisfactory for this purpose, but progressive manufacturers have learned that a properly refined No. 3 oil, although it runs high in color, can readily be used, inasmuch as most artificial leather products are of dark color. As is evident from the analyses previously recorded, the characteristics of the oil after refining are in no wise deleteriously affected.

In the leather trade castor oil finds rather extensive use both as a lubricant and as a soluble oil. Specifically, it is applied to belting directly as a sulphonated product and is also incorporated in a composite grease which may contain in addition to the oil such products as tallow, wax, paraffin, and vaseline. Belts treated with this mixture are made flexible and are prevented from cracking, all of which operates to increase the friction on the pulley.

It is stated that castor oil applied to leather in snowy weather keeps the leather soft and makes it waterproof; also that leather so treated is avoided by rats. It does not prevent a polish being produced on boots, and if applied once a week to leather shoes will cause them to last twice as long. Such treatment is particularly recommended if the leather has been wet. In such cases the oil should be rubbed in before the goods have dried. The softening of leather belts, harness, and other such leather goods is a further use to which castor oil is put.

Sulphonated castor oil is made by treating the oil with sulphuric acid under carefully controlled conditions of temperature and proportion of ingredients. The resulting product may be soluble or readily emulsifiable in water. It possesses the property of emulsifying other oils and greases and carrying them into the leather, which thereby becomes lubricated internally. Mineral oil may thus be carried into leather and impart to it a certain interior humidity. Sulphonated castor oil also facilitates the penetration of tannin into leather. It forms an ingredient of various creams, both black and colored, for rubbing patent leather.

Sulphonated castor oil is the basis of manufacture of emulsifying or soluble cutting oils used in connection with water. It may also be

used with mineral oils as a cutting oil when no water is used. It appears to have greater cooling qualities than most vegetable oils and does not gum or become rancid.

Sulphonated oils, particularly castor oil, have been used in producing the dye called Turkey red. Cotton cloth is treated with alum and immersed in a bath containing a solution of sulphonated oil (soluble in water). This is thought to form an aluminium oleate, which acts as a mordant to form a lake. Treating the mordant cloth with alizarine results in a bright red lake called Turkey red. The relative quantity of this color that is now used is considerably smaller than formerly, owing to the use of other colors of a similar shade.

For mantle dips this oil, as well as other vegetable oils, is used as a softener to render the coating of the mantle flexible. After the mantle has been dipped the coating on it has about equal proportions of cotton and the material from the oil.

In the manufacture of linoleum, castor oil has been found to be of advantage in imparting flexibility and toughness to the goods, somewhat the same as in imitation leather. Both No. 1 and No. 3 oils have been used, but since the finished goods are usually somewhat colored, no reason exists why an acid-free (refined) No. 3 oil would not be perfectly satisfactory.

Vegetable oils, notably castor oil, may be treated with sulphur and vulcanized, similar to rubber. This may be effected either by treating the oil with sulphur chlorid or by fusing it with sulphur direct. In the first case the product is known as "white substitute," due to the comparatively light color of the product, while in the second process the product is known as "black substitute." Sulphur chlorid may be added to the oil direct in proper equipment to control the temperature, or it may be added to a solution of the oil in some solvent. In either case the mixture, more or less hot, may be poured into molds or cooled, then ground and dried. The same treatment is pursued in the case of both the black and the white products. On heating, both products mix well with rubber; hence the name "substitute." The rôle of this product does not necessarily have to follow that of an adulterant in the sense that it is a mere cheapener. Certain rubber goods are not satisfactory unless mixed with other products. For example, the specific gravity of vulcanized oils is lighter than that of rubber and their incorporation offsets the increased weight due to mineral filler. They also impart softness to the product, desirable in certain fabrication.

It has been stated that so little sulphur chlorid is necessary for vulcanizing castor oil to make it set that it is difficult to work with. Some authorities state that castor oil must be used for floating substitute.

Among other uses in the rubber industry, castor oil finds application in the manufacture of gas tubing, insulating tape, and packing sheets.

Cellulose nitrate "dope" is greatly improved by the addition of 5 to 7 per cent of castor oil or treated tung oil. Greater elasticity of film and slow evaporation result.

Castor oil lends elasticity to varnish and has been stated to be an ingredient in certain artificial skin preparations, the formula for one of which is shellac, 1 part; alcohol, 3 parts; castor oil, one-fifth part. It is also used in retouching varnishes and in photographic-negative varnishes. In general, its use in varnish is to lessen brittleness and minimize the attendant property of chipping and peeling.

Castor soap is transparent, white, and quite hard. It dissolves in cold water without rendering the latter turbid. It lathers quickly and is very soluble.

In the manufacture of tire cement castor oil forms an ingredient of good thick shellac varnish. It prevents the bicycle rim from becoming hard and brittle.

Many salts of the aniline series are soluble in castor oil and advantage has been taken of the fact to prepare typewriter inks of great copying power, which permit large numbers of copies to be taken from the same impression. Hopkins¹ states that such inks are very little affected by extremes of dryness, moisture, heat, or cold. He also states that the oil-soluble colors are not affected by the moisture of the hand. Castor oil also prevents the ink from drying on the pad and at the same time "bites" the oil-soluble aniline color into the paper and prevents it from rubbing. Objection, however, to the use of the oil is that impressions from such inks are often surrounded by greasy marks caused by the fats spreading in the pores of the paper, and that the present practice is to make most of the stamping inks without grease by preparing mixtures of coal-tar dyes in glycerin.

In the manufacture of fly paper castor oil is a necessary ingredient. Various combinations of castor oil, resin, and other products are spread upon heavy paper with a common glue sizing. It is stated that sugar is sometimes used to make the product more attractive.

By heating nitrated oils to 130° C. or by oxidizing them with lead peroxid, rubberlike substances are obtained. Nitrated castor oil, made by nitrating with a mixture of 2 parts sulphuric acid and 1 part nitric acid, finds use in industry through its property of making homogeneous compounds with nitrocellulose. Such a mixture yields a product resembling ebonite. Solutions of nitrated oils in acetone are used as varnishes, as a basis for paint, and for enameling leather.

Castor oil finds a further use in the textile industry as a so-called "wool oil" (sulphonated castor oil), and very commonly is referred to as "castor-soap oil," both of which are used for degreasing special woolen products.

¹ Hopkins, A. A., ed. Scientific American Cyclopedia of Formulas . . . 1077 p., illus. New York, 1911.

The potassium soap of this oil is used as a solvent for water-insoluble substances, as the ethereal oils, cresols, and synthetic perfumes.

The extensive use of castor oil in medicine is due to its purgative property. Just to what this is due is a mooted question. Some think that the presence of small amounts of ricine or some other impurity imparts to the oil this property, which is lacking in the pure glycerid or oil. Others claim that this property is characteristic of ricinoleic acid (the acid radical of the oil) and quote in support of their contention the fact that pure ricinoleic acid itself is purgative. On the other hand, the statement that castor oil extracted from the seeds by alcohol is more effective than that made by expression lends color to the belief that the solvent plays a selective rôle in extracting more of the substance which possesses the purgative property.

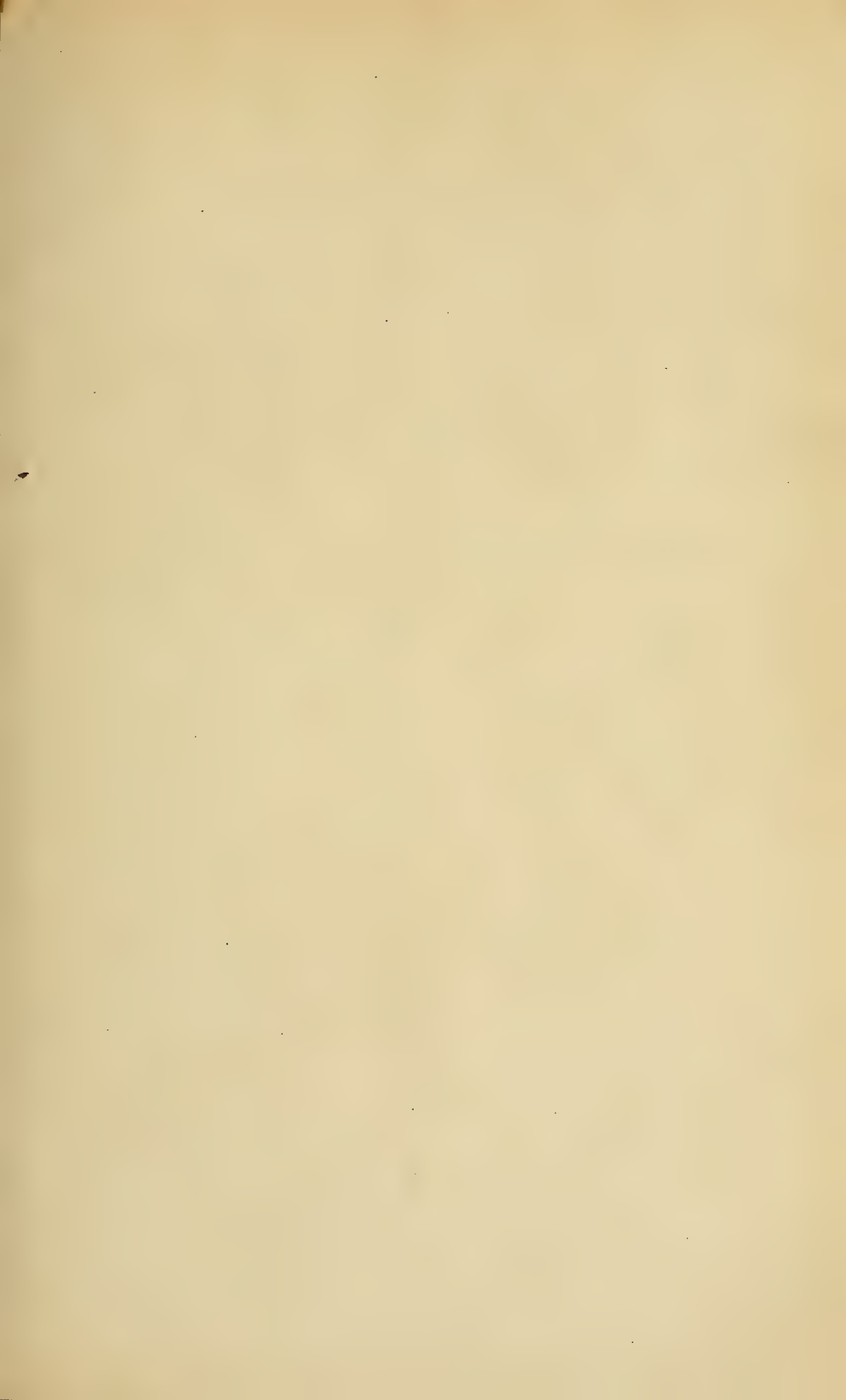
Much effort has been expended in attempting to remove from castor oil that property which makes it so repugnant to the taste and smell. Simple deodorization in a vacuum deodorizer is not altogether satisfactory. Everyone is conversant with the corner druggist's effort to mask it in soda water, peppermint, and other "sandwiches." Coloring it and adding a tincture of some of the common spices is about as satisfactory as any method. The following rather unique concoction is quoted (J. King, King's American Dispensary) for the reason that if such an unpleasant product as castor oil can be made to simulate a custard, even remotely, the fact should be made known to all:

I find it a very pleasant mode of administration to boil the dose of oil with about a gill of good sweet milk for a few minutes, sweeten with loaf sugar and flavor with essence of cinnamon or other favorite aromatic; it somewhat resembles custard in its taste and appearance and is readily taken by even the most delicate stomach.

CONCLUSIONS.

It is thus seen that although castor oil is one of the minor oils, its industrial use is increasing in a marked degree. While it is more widely known for its medicinal properties, its use is being constantly extended in a variety of industries.

The general method of manufacturing the oil in this country has been by crushing the beans in cage presses, but it has been found that the expeller produces an oil of satisfactory quality for all industrial uses and is perfectly satisfactory for aeroplane lubrication. Evidence has been obtained that a good grade of No. 1 oil can be obtained by extraction with volatile solvent. Highly acid dark oil can be refined by alkali but not highly bleached, while low acid oils can be refined and bleached to almost water white. Attention is called to the varied uses made of the oil and the possibility of finding markets for the more sluggish No. 3 oil.





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PLUMAGES OF STARLINGS.

Adult male (spring).

Young in juvenal plumage.

Adult female (spring).

Adult, male and female (fall).

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 868

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E. W. NELSON, Chief.



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ECONOMIC VALUE OF THE STARLING IN THE
UNITED STATES

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PROBLEMS RAISED BY THE STARLING.

MINDFUL of the disastrous results that have attended the introduction of exotic forms of wild animal life, farmers and bird lovers generally have looked with apprehension on the introduction and spread of the European starling in the United States. When the destructive careers of such introduced forms as the brown rat, the house mouse, and the English sparrow are considered, not to mention the annual toll in millions of dollars now being paid to satisfy the appetites of numerous insect pests that have been unwittingly brought from abroad, it is not to be wondered at that the deliberate importation and liberation of a considerable number of another species of bird that has since increased enormously in numbers should produce discussion.

Criticism came first only from those who foresaw in the light of previous experiences what might be the result of an unhampered spread of the starling. For a number of years the birds were confined to a small area about the place of importation, New York City, and there they were of interest chiefly to ornithologists. Their spread, however, in the early years of this century to the neighboring suburban and farming sections of New York, New Jersey, and Connecticut brought them more intimately in competition with our native birds and in close contact with growing crops. The starling was heard from immediately. Reports of its aggressive tactics against native birds became frequent: Flicker nests were said to be usurped by the wholesale; the houses of bluebirds and wrens were sharing a similar fate; young robins were being dragged from their nests and killed; and the food supply of certain native birds was being seriously reduced by the ever-increasing flocks of the foreigner. From farmers, too, came criticism: Cherries, berries, apples, and pears were reported damaged; in spring garden truck suffered; and in midsummer sweet corn was attacked by the birds. Even from the cities came complaints of the noise and filth connected with the large roosts of late summer and fall, established usually in a residential section. Few indeed had a good word to say for the newcomer. The occasional words of praise, however, were significant. Coming usually from careful observers, these appeared to indicate that, despite its bad points, the starling was destroying terrestrial insect pests at a rate surpassed by few, if any, of our native birds.

From such conflicting testimony it was apparent that an accurate estimate of the starling's worth could be secured only by extensive field observation, supplemented by careful laboratory examination of the contents of a large number of stomachs collected under diverse conditions and representative of every month in the year. It was imperative that this be done in order that an intelligent attitude might be reflected in legislation enacted for the bird's protection or control. Such work the Bureau of Biological Survey began in the spring of 1916, and the results of its investigation are discussed in the following pages.

SOURCES OF INFORMATION.

In conducting field work it was planned to visit as many points in the six States in which the starling was common in 1916 as one season's work by two investigators would permit.¹ Effort was

¹ Field work in the States of Connecticut, Rhode Island, and Massachusetts, as well as on Long Island, New York, was conducted by I. N. Gabrielson; and in Pennsylvania, New Jersey, and New York (except Long Island), by E. R. Kalmbach. This involved continuous observation from the beginning of April to the middle of October, a period in which all forms of damage of which the starling had been accused could be investigated. The authors collaborated in the examination of the material collected and in the preparation of the manuscript.

made to visit places from which complaints had come, and enough of these were investigated to give a good idea of the habits of the starling in areas where it had acquired an unfavorable reputation.

There were secured for this investigation a total of 2,466 well-filled stomachs, probably a greater number than has ever before been used for investigating the food habits of a single species of bird. Of these, 309 were of nestlings. Approximately two-thirds of the material was collected by representatives of the Biological Survey, the remainder being secured from reliable collectors, who at the same time submitted many economic notes of interest. Of these stomachs 1,250 were collected in Connecticut, 814 in New Jersey, 269 in New York, 62 in Pennsylvania, 43 in Massachusetts, 27 in Rhode Island, and 1 in Delaware. Besides these there were gathered 160 additional stomachs only partially filled with food. While these were not suited for estimating percentages, they furnished considerable information concerning food items.

In response to a circular letter sent under date of June 15, 1915, to numerous bird students, horticulturists, and practical farmers, 269 replies were received. The following questions, embodied in that circular, will give an idea of the data obtained:

1. About what year did the starling appear in your neighborhood?
2. Is it now common? When did it become so? Abundance as compared with other species.
3. Is the bird destructive to fruits? State kinds and, if possible, the approximate amount of damage.
4. Does the starling damage any other crops or property?
5. What are the relations of the starling to other birds?
6. Where plenty of nest boxes have been placed, has friction between the starling and other species decreased?
7. At what time of year do starlings begin to flock? Are they more destructive when in flocks than at other times?
8. Does the starling spend the winter in your locality?
9. From your observations do you consider the starling injurious or beneficial?

Besides the replies to these requests, correspondence from other sources has yielded many facts that have been incorporated in this bulletin.

DISTRIBUTION AND ABUNDANCE OF THE STARLING.²

The starling (*Sturnus vulgaris*) is native to all but the most northern parts of Europe, and also occupies the same latitudes in the western two-thirds of Siberia. Migration in fall takes the bulk of the species to countries bordering on the Mediterranean, and a portion to the warm latitudes as far east as Hindustan. Several related species and subspecies of starlings occupy adjacent sections and even portions of the same areas in the southeastern part of this

² Most of the data here presented concerning the introduction and spread of the starling in the United States prior to 1916 have been compiled by W. L. McAtee, of the Bureau of Biological Survey.

range. The starling has been introduced and established as an integral part of the fauna of Australia, Tasmania, New Zealand, South Africa, and the United States.

In North America attempts have been made to establish it at Cincinnati, Ohio (1872, 1873); Quebec, Canada (1875); Central Park, New York City (1877, 1887, 1890, 1891); Portland, Oreg. (1889, 1892); Allegheny, Pa. (1897); Springfield, Mass. (1897); Bay Ridge, N. Y.; and a few other localities. The bird gained a foothold at Portland, but now is scarce or extinct in that vicinity. Apparently the introductions of 1890 and 1891 into Central Park, New York City, are the ones which resulted in the permanent establishment of the species, and from this colony have been derived the thousands of birds now scattered over the northeastern United States.

The starling has not spread with the rapidity characterizing the English sparrow's occupation of the country. One reason is that this bird apparently does not travel in box cars; another, that it has not been introduced into so many localities nor carried from place to place by man. Nevertheless, it has steadily widened its breeding range and each year performs more and more extensive migrations.

For six years after its first successful introduction into Central Park the starling did not breed beyond the limits of greater New York. In 1896 it was confined as a breeding species to New York City, Brooklyn, and Staten Island. By 1902 it had reached Norwalk, Conn., and Ossining, N. Y., on the north; and Bayonne, N. J., on the south. By 1906, territory as far north as Wethersfield, Conn., and as far southwest as Trevese, Pa., was occupied. In 1908, Providence, R. I., and Philadelphia marked the extremes of its breeding range; and by 1913, Hadley, Mass., and Westchester, Pa., had been reached. The bird bred not far from Washington, D. C., in the summer of 1916 and in the same season was found breeding as far north as the southern boundaries of New Hampshire and Vermont, while toward the northwest it had extended its breeding range as far as Oneida County, N. Y. (see map, fig. 1). In its post-breeding wanderings the starling has been recorded from a much greater area, extending in 1916 from southern Maine to Norfolk, Va. On November 10, 1917, one specimen was collected as far south as Savannah, Ga. Inland it has been seen at Rochester, N. Y., Wheeling, W. Va., and in east central Ohio.

As a breeder the starling is by no means uniformly distributed throughout its range. In the first place, it is decidedly partial to thickly settled agricultural sections. It shows also a preference for the vicinity of the coast and the larger river valleys, and in its spread over the country lowlands are populated first. In the strip of territory from New York City to New Haven, Conn., where the starling in 1916 seemed to be the most abundant breeding bird, it was con-

fined to a narrow belt of low, flat, or rolling farm land within 8 or 10 miles of salt water, and, with the exception of the Housatonic

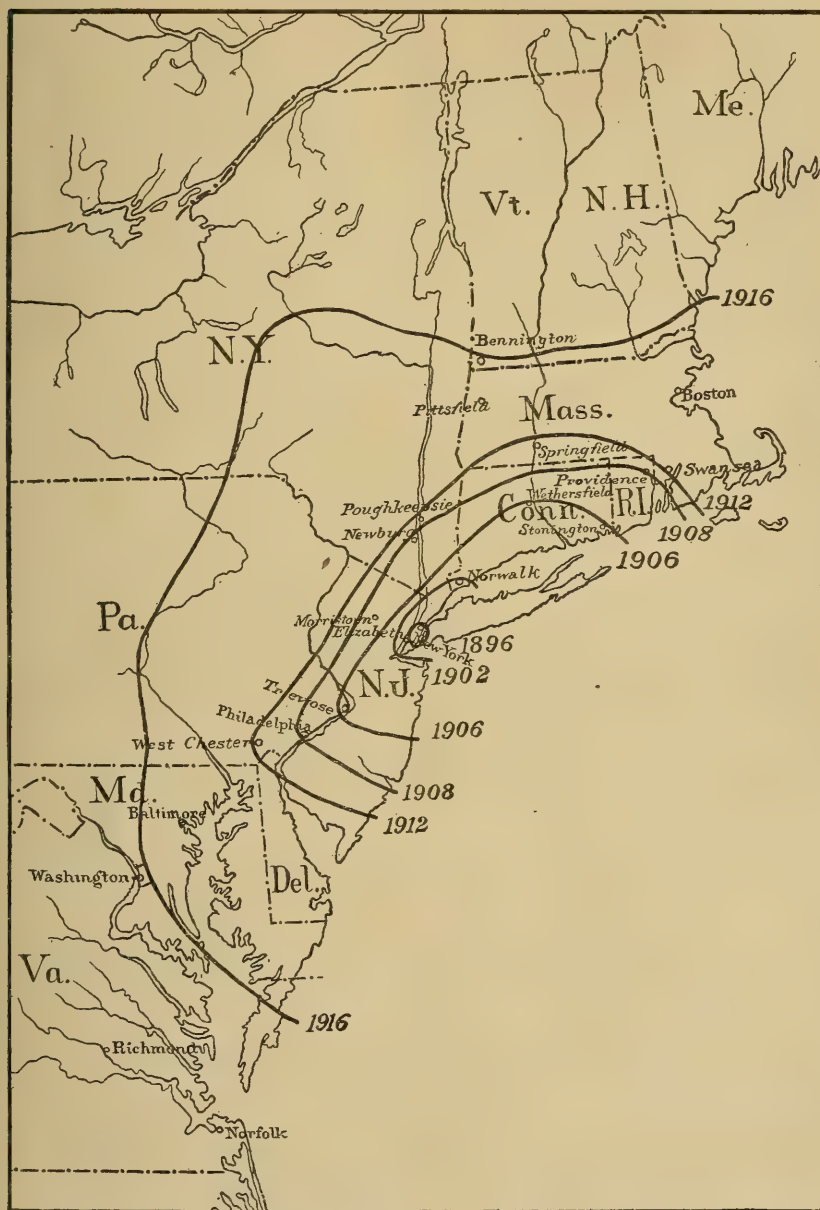


FIG. 1.—Breeding range of the starling at various periods from 1896 to 1916. Since 1916 this range has been extended so little that it is not indicated on the map.

Valley, there were few birds inland. East of New Haven the starling was restricted mainly to the shore. In most of the Con-

necticut River valley below Middletown, where it is narrow, with wild, rough land reaching often to the water's edge, the starling was scarce; but north of Middletown, where the valley widens until several miles of rich cultivated bottom land lie between the wooded hills, the bird was very abundant. Up the river as far north as Springfield, Mass., the starling was as common a breeder as the robin. North of Springfield it was not present in great numbers, although favorable conditions for food and nest sites prevailed. According to a count made in 1916 by the bird club of Springfield, that city contained a breeding starling population of 5,000. Amherst, Holyoke, Northampton, and Greenfield, Mass., had colonies of varying sizes, those of Amherst and Greenfield approximating 1,000 and 500, respectively. In eastern Massachusetts and in Rhode Island the birds were only local in distribution. On Long Island a line drawn from Oyster Bay on the north to Bay Shore on the south roughly marked the eastern boundary of the region of abundance. East of this line the birds were generally, but not abundantly, distributed on the north and south shores. They were absent from the center of the island except for a few in cultivated clearings.

In 1916, the starling was extremely abundant in northeastern New Jersey, where it had been established about the cities of Newark, Paterson, Montclair, Elizabeth, and Plainfield for at least 15 years. It was also quite generally distributed throughout Somerset, Middlesex, Hunterdon, and Mercer Counties. In the northern parts of Monmouth, Burlington, Camden, and Gloucester Counties it was locally abundant. There were very few, however, in the pine barrens in the southeastern part of the State, or in the hilly sections to the north, comprising all of Sussex and Warren Counties and parts of Morris, Passaic, and Bergen Counties. Up the Hudson the starling's abundance was restricted to the vicinity of the larger towns, Peekskill, Newburgh, and Poughkeepsie having the greatest numbers. The narrowness of the valley prevented a general distribution along the lower Hudson. In Pennsylvania the bulk of the starling population was still confined to the vicinity of Philadelphia.

The familiarity of the starling with human abodes, and the daily visits to a single feeding ground of the same post-breeding flock are the two factors that have given many persons an exaggerated idea of the abundance of the species. Few have attempted to estimate relative numbers during the breeding season. It is believed that in all of Hudson County, most of Essex and Union Counties, and the southeastern and southern parts, respectively, of Passaic and Bergen Counties, New Jersey, the starling in 1916 had reached a state of maximum abundance, beyond which it will not increase as a breeder. The same may be said of the area immediately to the east and northeast of Brooklyn and New York City and extending along the Connecticut

shore as far as Bridgeport. It is possible, of course, for the size of post-breeding roosts and winter flocks to be further augmented in this section by an increased breeding population in adjacent country. Taking this area as a whole, the starling about equaled the English sparrow as a breeder. In the residential sections of some of the cities it outnumbered the sparrow, but it in turn was greatly outnumbered about the freight yards, markets, business streets, and dumping grounds; and even in many of the rural sections the sparrow predominated.

Beyond this area of maximum abundance, centers of starling population, where the starling as much as equaled the English sparrow as a breeder, were quite restricted and often isolated from other colonies by many miles. Consequently, exaggerated ideas regarding the average abundance of the starling throughout its range were also held by persons living in the vicinity of localized colonies. A distance of but a few miles will at times reveal great differences in starling abundance. At Bernardsville, N. J. (July 22-25), starlings were too scarce to make collecting profitable, although at Mendham, only 6 miles to the north, the brood of the year was so abundant about the farms close to the village that the birds inflicted severe damage to the cherry crop. At Somerville, N. J. (June 5-8), only 10 miles from Plainfield, a center of starling population, the same unfavorable collecting conditions were met. At Freehold, N. J. (September 18-October 1), the location of a roost in the town accounted for an unusual abundance of starlings on the near-by farms, especially in early morning and late afternoon. After the roost had been eradicated, the starling could not be placed any higher than tenth in a list of birds of the surrounding country, arranged according to their abundance.

In 1916, there was a vast area along the borders of the starling's range where the bird was too scarce to be of any great economic significance. This applied to most of Massachusetts and Rhode Island; New York, north and west of Kingston; Pennsylvania and Delaware, outside of a 30-mile radius of Philadelphia; and New Jersey, south of a line drawn from Salem to Toms River. In this region many farmers were wholly unacquainted with the bird and very few had complaints to make.

With a knowledge of the starling's habitat and food preferences, both in Europe and in this country, and of the bird's ability to adapt itself to new environment, some conjecture may be ventured as to its ultimate distribution in the United States. Until 1916, the Allegheny Mountains appeared to be an effective barrier against progress to the west, but now that numbers have been reported at points west of the divide, the spread through the low, fertile farmland of Ohio and Indiana may be rapid. There appears no reason why

the starling, once established in the Mississippi Valley, should not readily extend its range as far north as the middle of Michigan, Wisconsin, and Minnesota. To the south, it will probably go nearly, if not actually, to the Gulf coast, though it may always be scarce as a breeder in the southern part of this area. To the west, the Great Plains with their scarcity of suitable nesting sites, and back of them the Rocky Mountains with their high altitudes, will bar the starling for many years from reaching the Great Basin or California by either a northern or a southern route.

DESCRIPTION OF THE STARLING.

Even in areas where the starling has been long established uncertainty exists as to its identification. Post-breeding flocks of red-winged blackbirds are often called starlings, and the damage they do is often attributed to the latter. The great differences between the plumages of the young and of the adults, as well as the great change in the appearance of the old birds from fall to spring, also lead to confusion. The starling, however, bears several conspicuous marks of identification, and when these are borne in mind, one will have little trouble in recognizing the bird.

The adult starling is about $8\frac{1}{2}$ inches long, and its weight is about equal to that of the robin; but its short, drooping tail gives it, when at rest, a chunky, humpbacked appearance. From early spring until the middle of June the adult bird may be singled out at a distance by its being our only black bird having a rather long, sharp, yellow bill. In the male the base of the lower mandible is somewhat darkened with livid; in the female these parts are simply paler yellow. After the breeding season, and coincident with the molt, the entire bill darkens until it is nearly black. The molt is usually completed by the middle of September and leaves the starling a much changed bird. The feathers of the sides of the head, breast, flanks, and underparts have white tips, so that from a distance the bird has a gray, mottled appearance. At close range, however, the starling is a handsome bird in this plumage; the dark parts of the feathers of the throat, breast, and flanks are resplendent with iridescent reflections of purple, green, and blue; while on the back, with its green and bronze iridescence, the feathers are tipped with brown. The tail and wings are dark, some of the feathers of the latter being edged with brown. During winter most of the white tips to the feathers on the breast and underparts wear off, leaving the bird dark below, with the iridescent reflections still present. (See frontispiece.)

On leaving the nest the young are a uniform dark olive-brown on the back, and below they are at first somewhat streaked with lighter markings, but soon become unicolor; the throat is white or buffy. The first molt begins about the same time as that of the adults.

The first new feathers appear on the sides of the breast, the flanks, and the center of the back, while the plumage of the head is the last to change. During July, August, and early September, young birds in all stages of the molt may be found. When the plumage has completely changed the young can not with certainty be distinguished from the adults, although they tend to have larger white tips to the feathers below.

In flight the starling may be confused with a few other species. From its habit of sailing on fixed wings for considerable distances it is often mistaken for the purple martin, but a little watching will reveal the starling's greater speed. When in flocks starlings may be distinguished from other gregarious species with which they often associate by the wonderful coordination of action between the individuals of the flock, their rapid wing beats, great speed, and ability to alter direction instantly.

In searching for food the starling walks rather rapidly and with little change in pace, keeping up a continuous zigzag course when on grassland, seldom hesitating unless to pick up food.

The contention of many bird lovers that the starling's lack of song is a good reason for not allowing it to supplant native songsters is open to controversy. While its notes, outside of a clear whistle or two and a coarse rasping note of alarm, are subdued and lack melody, should one chance to be close to a male starling putting forth his best efforts, the results will be as fascinating as the more celebrated whisper songs of the catbird or of the brown thrasher. The starling is a mimic par excellence and has the notes of a number of our native birds already in its repertoire, a fact that has often led to error in identification when the observer placed too much confidence in notes alone. Perhaps the bird most frequently imitated is the wood pewee, whose plaintive "pee-a-wee" is reproduced with such delicate skill that it can not be distinguished from the song of the woodland flycatcher itself. The mellow tones of the bluebird's call are given with almost equal fineness. In areas where the bob-white is common its two-noted whistle is readily taken up by the starling and executed in a way that closely resembles the original. Notes of the red-winged blackbird, grackle, field sparrow, flicker, blue jay, Carolina wren, and English sparrow also are given, but less frequently. Young starlings have a harsh, hissing, or rasping note, which seems to have its origin as a feeding call, but is given for some time after leaving the nest.

LIFE HISTORY.

During the first week in April the wintering flocks of starlings begin to decrease in numbers as the birds mate and wander off in

search of nesting sites. By the middle of the month this process is completed, although the birds often return to the old roosts for the night until nest building is started.

For nesting sites, old woodpecker holes, natural cavities in trees, bird houses (particularly those intended for bluebirds, flickers, and martins), and cornices or crevices about buildings are most frequently chosen, although nests have been found on fire escapes, hay tracks, and barn doors, behind window shutters, and even in open boxes erected for pigeons. In fact, any cavity, regardless of size of opening or depth, may be utilized if the starling is able to enter it at all. The nesting sites chosen are frequently poorly protected from rain; consequently the nests are foul and damp.

In the mere construction and occupancy of their nests, starlings have been the source of some complaint. Being sturdy birds and equipped with bills well suited for tearing things to pieces, though not especially adapted to chiseling healthy wood, they will at times do damage to roofs not recently shingled. The clogging of hay tracks or tracks of barn doors with their nests is occasionally a source of trouble, and the infesting of the immediate vicinity of their homes with bird lice is complained of when they build about water tanks, poultry houses, etc. The filthiness of their nests, due to the great quantity of excreta deposited, is also a common complaint, especially when the birds choose some spot immediately above the doorstep for their breeding operations. This condition prevails most often during the latter stages of the nestling life, when the parent birds are unable to remove all the accumulation.

The height at which starlings nest is variable, the lowest nest cavity observed being 2 feet from the ground and the highest fully 40 feet. When they nest in trees the cavities usually range from 10 to 25 feet from the ground.

The nest itself is usually composed almost entirely of dry grasses and is sufficiently large to fill the bottom of a cavity 3 to 4 inches deep. The interior of the nest will approximate 3 inches in diameter. A little green foliage, usually a few leaves taken from a near-by branch, is dispersed throughout the grassy structure. The interior is lined sparingly with feathers of domestic fowls. Straw, corn husks, string, and cloth are other materials sometimes used in nest building. Nesting sites used for several years in succession gradually fill up with a partly decayed mass of these materials. From one nest in the cornice of a sawmill a good half bushel of material was removed.

The eggs are of a pale-blue color and number from 3 to 6 to the set. Incubation lasts about 12 days. The young remain in the nest from 2 to 3 weeks, or until they are able to fly, which they do well on their first attempt. This habit, combined with the protected nest

sites, tends to reduce the mortality among young starlings much below that of many other species.

Nestling starlings are fed by the parents largely on insects. For the first week both parents take part in the feeding operations, but in several nests that were under observation the female was left to do all the work during the later part of the nestling period. When 3 or 4 days old the young are very noisy and give the feeding call in lusty chorus in response to almost any sound. Later, they learn to distinguish the approach of the parents and respond only to their notes or appearance. Other noises or vibrations cause them to crouch silently in the bottom of the nest, and no amount of coaxing will persuade one of them to stir or make a sound.

Two broods are usually raised each year and sometimes there are three. The first of these leaves the nest about June 1 and the second late in July. Fledglings which may have been from either a belated second or third brood just from the nest were collected as late as September 12, at Bay Shore, N. Y.

As soon as the first brood leaves the nest small flocks of young starlings can be found feeding on grasslands or roosting at night in trees or buildings. These flocks grow rapidly in size and by mid-July often number into the thousands. During the day no adult birds are found in these early flocks and very few appear until after the completion of the molt in September; both old and young, however, occupy the same nightly roost. These post-breeding flocks usually select a roosting place in trees in the residential sections of cities and are there the cause of much complaint. Occasionally a roost will be formed in a cat-tail marsh or in a building, but this is the exception rather than the rule.

At a roost in a marsh along the Hackensack River an opportunity was afforded to watch the starlings congregating. As early as 3 o'clock in the afternoon flocks of a dozen or two could be found gathering in the hayfields in the vicinity, or perching on dead chestnuts, singing and preening their feathers. Most of these were juveniles with the molt extending up as far as the neck. They would fly alternately to the hay stubble, which was heavily infested with grasshoppers, and then to the tree tops when flushed. By 4 o'clock a flock of a hundred or more had gathered. In the scramble for grasshoppers and crickets, one or more momentary conflicts between competitors would be almost continuously in progress and, as the flock progressed across the field, a rolling aspect was imparted to it as birds in the rear would fly forward to new territory.

With the approach of evening the birds would rise and perform numerous flight evolutions, in which they displayed wonderful coordination of action. This was best observed when they would fly in the direction of the sun, and the flashes of light coming from

their glossy backs appeared as coming from a single mirror instead of from several hundred bodies acting independently but in perfect unison. After a minute or two of such flight the flock would sometimes seem suddenly to lose this ability of coordinated action and the individuals would spread out in a long wavering line, breaking up into several groups before alighting. As dusk approached, the birds had worked their way toward the Hackensack River, where they gathered in compact flocks, singing in the tree tops along the bank. (Pl. II.) A few were seen feeding with a large number of red-wings on the tidal flats along the edge of the marsh. When darkness finally came the starlings in the tree tops sailed out over the marsh and joined their relatives, perching on the cat-tail flags for the night.

The behavior of starlings at all other roosts which came under observation was much the same, except in one instance, at Glenn Cove, N. Y. Here the birds went through the usual maneuvers and settled in company with a great number of grackles in a grove on the outskirts of town. Late in the evening the entire flock rose in a body and flew to the permanent roost half a mile or more away, behaving much the same as do crows in gathering at a winter roost.

These summer roosts are often inhabited by several species. Grackles or starlings usually form the bulk of the occupants, but there may be also numbers of cowbirds, red-winged blackbirds, English sparrows, and robins. An unusual roost was established at Washington, D. C., in August, 1917. At a point on the Mall, where grackles had roosted for years and starlings had been found for several seasons, a great mixed flock congregated, consisting of 8,000 or more purple martins, about 1,000 grackles, 300 starlings, and a few swallows (probably rough-winged swallows).

The birds from these summer roosts frequently have a definite feeding route. For example, the starlings from the Glenn Cove roost flew south and east for about a mile to commence feeding, and from 5 to 7 o'clock each morning could be found in almost the same locality—an abandoned field. From here they worked in a well-defined circle, appearing at 4 o'clock in the afternoon in an orchard three-quarters of a mile north of the roost and feeding there and in the surrounding fields until going to the trees for the night.

In October or November the starlings voluntarily abandon these tree roosts and resort to church towers, barns, or other buildings for shelter. Here they gather nightly until spring, when the flocks are broken up by the mating impulse. A local estimate of the number of birds in such a roost in a church tower in Norwalk, Conn., varied from 10,000 to "a million," but an approximate count revealed the fact that not more than 1,000 birds were roosting there in April, 1916.

Although the starling remains in some numbers throughout the breeding range during the winter, it exhibits a certain migratory



STARLINGS AT HACKENSACK, N J., ROOST.

B17290

Photograph taken at about sundown while most of the birds were singing. A few moments later these starlings, along with hundreds of others, sailed out over a near-by marsh, where they roosted among cat-tails in company with many red-winged blackbirds.



movement. All the birds in one locality collect into a single roost, but in addition to this there is a large increase in the flocks along the seacoast and a considerable movement southward from the breeding area. For three years a varying number of starlings appeared in a fall roost in Washington, D. C., before breeding birds were first found in 1917. Other localities south of the breeding range have also reported wintering flocks for several years before the birds have become permanent residents.

ECONOMIC STATUS IN OTHER COUNTRIES.³

While the behavior of the starling in its native home and in countries to which it has been introduced can not be interpreted as a certain indication of its conduct under the new conditions it will meet in this country, its activities elsewhere will serve to call attention to its capabilities for doing good or harm. Throughout most of its breeding range in Europe, particularly in France, Germany, and Hungary, the bird is held in great esteem and is encouraged, by the erection of nest boxes, to breed about farms and gardens.

The chief German authorities, with one exception, have considered the starling more beneficial than injurious. The birds there do considerable damage to grapes and cherries, and to a smaller extent injure various cultivated berries. On the other hand, they feed freely upon injurious snails and slugs, beetle larvæ, caterpillars, maggots, and grasshoppers. Among their prey are such pests as ticks, gadflies, stable flies, cockchafers, fern beetles, pine weevils, fir weevils, spruce moths, and field and mole crickets.

French authors mention damage by the starling to olives and grapes, but are unanimous in declaring the species useful. It is significant, moreover, that, although one of their articles was published in a viticultural journal, damage to grapes, one of the greatest points made against the starling, was not considered sufficient to exclude the bird from the list of useful species.

In Belgium the starling is said to be very useful and its damage insignificant, as it prefers an insect diet. It eats about the same pests as in Germany, and in addition wireworms, grass moths, plant lice, and oak leaf-rollers.

The late Otto Herman, distinguished Hungarian ornithologist, asserts⁴ that, taking its feeding habits of the whole year into consideration, the starling does a thousand times more good than harm and richly deserves protection. Starlings have rendered particularly efficient service during locust plagues in Hungary.

The single Swiss author consulted gives the bird about as much adverse criticism as praise; and a communication from Tunis states

³ The data presented under this topic were compiled by W. L. McAtee, of the Biological Survey.

⁴ Herman, Otto, *Nutzen und Schaden der Vögel*, Leipzig, p. 181, 1903.

that on isolated plantations migrating starlings sometimes take the entire olive crop.

In 13 of 18 general articles on the starling in Great Britain it is stated that the bird is more beneficial than injurious; one article says that while the bird is valuable now, its habits are undergoing a change for the worse, and four state that although very useful in grasslands and forests, the starling is entirely too numerous for the best interests of fruit growers. Exhaustive investigations of the bird's habits have been made by Gilmour, Newstead, Collinge, and the national board of agriculture. After reviewing the whole question of the starling's economic status the board of agriculture concludes⁵ that "on the whole * * * the information at present collected goes to show that, in view of their great partiality for insect food, starlings are, from the forest standpoint, entirely useful, whilst in agriculture and gardening their usefulness far more than outweighs the occasional harm done."

Summing up, it may be said that in Europe the verdict on the starling is distinctly favorable; of 35 works dealing in a general way with the economic status of the bird, only 7 report adversely. It is noteworthy, moreover, that the findings of all the thorough and more scientific investigators have been in favor of the species, although some authors admit that at present starlings are too numerous in some localities.

In most countries where the bird has been introduced, the case is different. In Australia and Tasmania testimony concerning starlings is generally unfavorable. Their great faults are driving away native birds and preying upon fruits. They have by no means lost their insectivorous tastes in their new home; in fact, they are credited with suppressing plagues of grubs and crickets which destroy grain and grass. Their numbers have become so great, however, that after the breeding season enormous flocks band together and at times descend upon orchards, vineyards, or gardens, where they make great havoc with the crops.

The introduction of the starling into New Zealand does not seem to have resulted so unfavorably as in Australia. In 1907, just 40 years after the first importation, James Drummond published an account of the activities of the species in that country.⁶ His conclusions were based on the testimony submitted by many farmers who had experience with the birds, and were to the effect that the starling was one of the most valuable of insectivorous birds.

⁵ Board Agr. and Fisheries (London), Leaflet 45, Rev. ed., 4 p., June, 1905.

⁶ New Zealand Dept. Agr., Div. Biol. and Hort., Bull. 16, 1907.

FOOD HABITS IN THE UNITED STATES.⁷

Examination of 2,157 stomachs of adult starlings⁸ showed that 57 per cent of the annual food was animal and 43 per cent vegetable. During the months from April to November, inclusive, excepting July, animal matter made up more than half the food, the maximum being taken in April and May (91.22 per cent and 94.95 per cent, respectively). In July, with the great abundance of mulberries and cherries offering an unlimited supply of luscious fruit, of the 52.67 per cent vegetable matter taken, nearly all, or 50.74 per cent of the total, consisted of these two items. In February, animal food dropped to the lowest point in the year, 28.17 per cent. The average, however, for the four winter months from December to March was 31.5 per cent, a remarkable showing when circumstances are considered. The great majority of these winter stomachs were collected in New Jersey and Connecticut, and in view of the usual climatic conditions in these two States it seems noteworthy that starlings were able to secure such a relatively high proportion of animal food.

ANIMAL FOOD OF ADULTS.

INSECTS.

Of the total yearly food of the adult starling, 41.55 per cent is composed of insects, a greater proportion than is shown in the food of most of our native birds of similar habits. The monthly percentages of insect food are as follows: January, 27.66; February, 23.81; March, 23.87; April, 32.61; May, 49.94; June, 52.26; July, 41.98; August, 56.92; September, 52.83; October, 57.8; November, 54.0; December, 25.2.

During winter many hibernating insects or the bodies of dead insects which have been preserved by the season's cold are eaten. Among these, beetles, weevils, stinkbugs, grasshoppers, caterpillars, and lepidopterous pupæ are conspicuous. As the fields become more thoroughly gleaned the percentage of insects eaten decreases, until in February and March it reaches its minimum, 23.81 per cent and 23.87 per cent, respectively. In April, as insects begin to appear in numbers, the percentage rises, and during the months from May to November, except in July, when the starling temporarily abandons an insect diet to feast on wild fruit, over half the total food is insects.

As the character of the insect food of a bird is of vast importance in fixing its economic status, the different groups of insects in the food of the starling will be taken up in the order of their importance.

⁷ Graphic summaries of the food habits of adult and young starlings are presented in figures 2 and 3 (p. 38 and p. 45, respectively); and the relative proportions of the various food elements are set forth in percentages in Tables II and III (p. 39 and p. 44, respectively).

⁸ Included with the stomachs of the adult birds here discussed are stomachs of juvenile birds that had left the nest and were shifting for themselves.

It must be remembered that in ascertaining the economic worth of a bird not all the insects eaten can be placed to its credit, as many are of great value because of their predacious or parasitic habits.

COLEOPTERA (Beetles).

Of the 41.55 per cent of insect food consumed by the starling, nearly half (19.59 per cent) consists of beetles. These are divided among numerous families, but weevils, carabids, and scarabæids, in the order named, are of the greatest importance.

The Rhynchophora, or weevils, stand first among the Coleoptera in the proportion of food furnished, 8.5 per cent of the starling's food being from this source. In feeding on this group the starling is doing a very useful work, as the snout beetles include some of the most destructive insects with which man has to deal. Weevils are eaten every month in the year. The smallest quantity taken in any one month was 3.13 per cent in October, and the largest, 20.16 per cent in a winter month, February. An examination of the monthly percentage table (p. 39) shows that there are two periods of the year in which weevils form over 10 per cent of the food. The first is in July (13.36 per cent) and August (10.91), when many species are emerging; and the second is in January (14.10) and February (20.16), when the starlings are feeding on hibernating forms.

One of the most interesting food habits of the starling is in its relation to the clover leaf weevil (*Hypera punctata*), a European insect which has long been introduced and acclimated in the United States and which does serious damage to the clover crop in some seasons. It is known that the starling habitually feeds on this insect in England, but it apparently goes far beyond its normal habit in feeding on it in this country. Nearly half (1,125) of the 2,301 adult birds examined had eaten clover leaf weevils, and 12 had taken their larvæ. Of these no less than 54 had taken 10 or more weevils for one meal and 106 had taken from 5 to 10 weevils. The largest number of larvæ eaten was 49, taken by a bird collected in New Jersey in May. These formed 38 per cent of the stomach contents. Twenty-six was the greatest number of adults from one stomach, and these, together with 6 other weevils, formed 95 per cent of the food. In February, 288 of the 398 stomachs examined contained remains of this beetle, and in January, 33 of 84. In July, 211 of 375 birds and in August, 216 of 347 had taken this weevil.

In every month of the year the starling is searching the grasslands and weed patches for the clover leaf weevil. The high percentage revealed in January and February would seem to indicate that *Hypera punctata* hibernates in far greater numbers than has been commonly believed, for it is scarcely conceivable that so many dead insects would be left in as good condition as are many of these this



FIG. 1.—STOMACH CONTENTS OF JUVENILE STARLING.

B845M

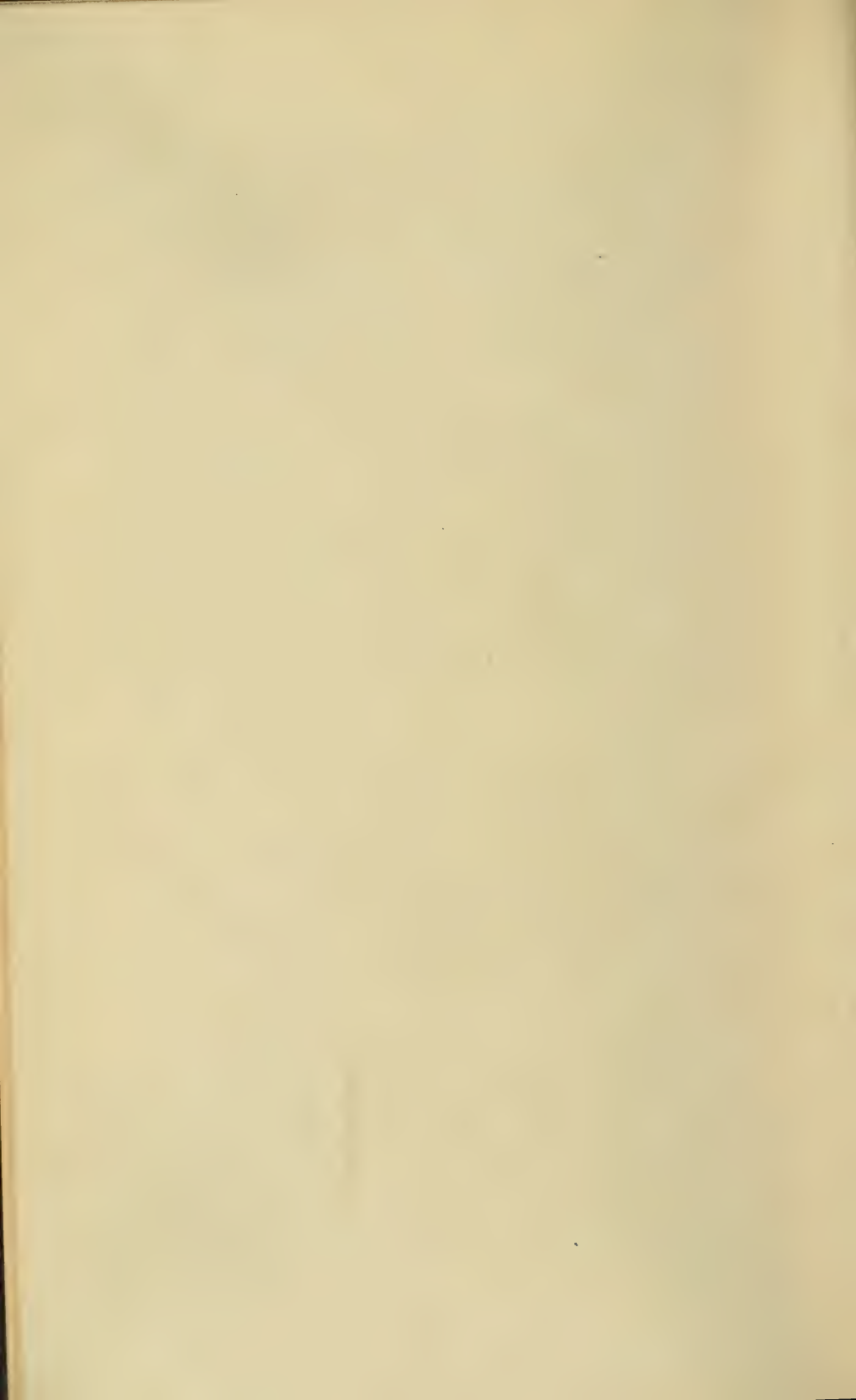
Nearly 95 per cent of this bird's food consisted of the remains of 26 clover-leaf weevils, the heads, thoraxes, and wing covers of which may be seen at the left of the picture. The large mass in the upper right-hand corner is additional débris of the same insects; below it are parts of a clover-root weevil; and in the lower right-hand corner are fragments of the skin of a cultivated cherry.



FIG. 2.—STOMACH CONTENTS OF JUVENILE STARLING.

B844M

Except for a few bits of vegetable rubbish, shown in the extreme lower right-hand corner of the picture, all of this bird's food consisted of flies in one stage or another of development. There were present 1 adult and 76 puparia of Muscidae, at least 85 sarcophagid larvae, and another puparium. This bird apparently had been feeding in the vicinity of carrion or garbage.



late in winter. For example, one bird from Massachusetts in January had eaten 14 of these weevils and 4 others, which made a total of 26 per cent of its food. A Connecticut bird taken in the same month had also eaten 14 of these weevils, which formed 32 per cent of the food. In these two months 14 of the birds had taken more than 5 *Hypera* at a single meal. (Pl. III, fig. 1.)

Another weevil eaten in considerable numbers is the lesser clover leaf weevil (*Phytonomus nigrirostris*). Seventy-three of the 2,301 adult birds had fed on this insect. The greatest number taken was 9 by each of 2 birds. The clover root curculio (*Sitona hispidula*), the larvæ of which feed on the roots of various species of clover, is also a favorite article of diet, having been taken by 505 adult starlings. It was found most abundantly in the same months as the clover leaf weevil, as 27 of 84 birds taken in January, 119 of 398 taken in February, 83 of 375 in July, and 86 of 347 in August had eaten it. The birds frequently took numbers of this species, 36 having taken 5 or more. An August bird from Pennsylvania had eaten 30 adult clover root curculios, and one from New Jersey had taken 31. The closely related weevil *Sitona flavescens*, which has similar injurious habits, is preyed upon to a less extent, only 33 of the 2,301 adults having eaten it. One of these, however, taken in Connecticut during August, had devoured 17 of the weevils, and several others had taken 2 or more.

The strawberry crown girdler (*Otiorhynchus ovatus*), the larvæ of which feed on the roots of strawberries and other plants, had been eaten by 60 adult starlings, and the closely related weevil (*Otiorhynchus sulcatus*) known in Europe as the black-vine weevil, had been taken 7 times. *Barypeithes pellucidus*, another weevil known to attack strawberries and found in southern New England and adjacent States, had been taken by a single bird, which had made 75 per cent of its meal on 167 individuals.

In point of numbers taken, *Sphenophorus*, a group of destructive weevils known as billbugs, which bore into the seeds and stems of grain, stands next to the clover weevils, as at least 225 starlings had eaten them. Of these the "bluegrass billbug" (*S. parvulus*), which had been eaten by 104 birds, was most frequently taken. These insects sometimes do considerable damage to timothy. Five other species of this genus, all of them injurious, were taken in varying numbers by the birds. *Phyxeles rigidus* was found in 90 stomachs, one of which contained 13 individuals.

As the starling stomachs examined often contained several species of these injurious weevils, a few of the more interesting ones are mentioned here. In a July stomach from Pennsylvania 20 *Hypera punctata*, 14 *Sitona hispidula*, and 2 *Sphenophorus* sp. formed 95

per cent of the contents. A New Jersey bird taken in the same month had made 60 per cent of its meal on weevils, as follows: 3 *Hypera punctata*, 9 *Sitona hispidula*, 1 *Sitona flavescens*, 1 *Phytonomus nigrirostris*, 1 *Sphenophorus parvulus*, and fragments of one other weevil. An August bird taken in Connecticut had eaten 13 *Hypera punctata*, 3 *Phytonomus nigrirostris*, and 1 other weevil, making of these 72 per cent of its meal. Another bird from the same State collected in January had eaten 9 *Hypera punctata*, 2 *Sitona hispidula*, and 3 *Sphenophorus parvulus*, which formed 50 per cent of the total stomach contents.

From the foregoing data it is evident that the starling is a very effective enemy of such weevils as feed on grass or forage crops. This is particularly noticeable in regard to the clover pests, and it is safe to assert that *the starling is the most effective bird enemy of the clover weevil in America.*

It seems natural that the Carabidæ, or ground beetles, being to a large extent grass-inhabiting forms, should be present in the starling's food, of which they constitute 5.71 per cent. As this family contains both beneficial and injurious insects it will be necessary to consider it in some detail. During the months from April to October, inclusive, carabids furnish a considerable portion of the food, varying from 4.56 per cent in October to 13.02 in August. They are among the first beetles to appear in spring, and are promptly sought for by the starling. This is strikingly shown by their increase in the food from 1.07 per cent in March to 7.31 per cent in April. The maximum consumption of these insects is in August and September (13.02 per cent and 12.93 per cent, respectively, of the food). During the other months the number taken is small and in no case forms much more than 1 per cent.

Inasmuch as ground beetles seldom occur in nature in as great numbers as some of the plant-feeding beetles, their presence in starling stomachs is usually limited to a few individuals. They were found, however, in moderate numbers in nearly every stomach collected during the summer.

Comparatively few of the large predatory carabids of the genera *Carabus* and *Calosoma* are captured by the starling, as, of 2,301 birds, only 20 had eaten the former and 3 the latter. *Pterostichus*, a genus of small beetles living largely on animal matter, was found more frequently, 160 birds out of 2,301 having fed on it. One member of this genus, *P. lucublandus*, a medium-sized beetle, was found in 102 stomachs. Thirteen birds had captured members of the genus *Dicælus*, a highly beneficial group which feeds on insects, and 67 had eaten various species of *Platynus*, beetles with somewhat similar food habits. Ninety-five stomachs contained members of the genus

Chlænius, also insectivorous, and in 36 were the remains of *Casnonia pennsylvanica*, a curious and easily recognized little carabid.

By far the greater part of the carabids eaten by the starling are those that are known to be somewhat vegetarian in habits, notably certain members of the genera *Harpalus* and *Anisodactylus*. These beetles feed to a considerable extent on grass seeds and pollen and, therefore, can not be classed among the more beneficial carabids. Eight species of *Harpalus* were identified in the material examined, and in 277 stomachs the identification could be carried down only to the genus. *Harpalus caliginosus*, the largest member of the group, was identified in 144 stomachs, and *H. pennsylvanicus* in 79. One hundred and thirty-eight birds had eaten beetles referable to *Anisodactylus*, but these could not be specifically identified. Of the four species of this genus found in starling stomachs, *A. rusticus*, identified in 65, was the most common. Carabids of the genus *Amara*, that are to a considerable extent vegetarian in their feeding habits, were eaten by 151 of the starlings examined; *Scarites subterraneus* was found in 14 stomachs; and *Agonoderus pallipes*, which is injurious to sprouting corn, in 3.

When feeding heavily on carabids, the starling usually secures a number of species. For instance, a bird shot in New Jersey in April, that had made 91 per cent of its meal on carabids, had eaten 1 *Amara*, 1 *Anisodactylus*, 1 *Platynus cupripennis*, and 1 *Agonoderus*; while a June bird from the same State had taken 20 *Amara pennsylvanica* and at least 2 other carabids, these forming 75 per cent of the stomach contents. A July bird from Connecticut that had made 13 per cent of its meal on beetles of this family had varied the menu by taking 2 *Pterostichus lucublandus*, 1 *Bembidium quadrimaculatum*, 2 *Harpalus* sp., 2 *Anisodactylus rusticus*, and 1 other carabid. A New Jersey bird taken in the same month had devoured 19 *Amara*, 3 *Agonoderus*, 2 *Anisodactylus*, 11 *Harpalus*, and 2 other carabids, which totaled 84 per cent of the food. A Pennsylvania bird collected in August had eaten 1 *Harpalus caliginosus*, 2 *H. pennsylvanicus*, 10 *H. erythropus*, 5 *Pterostichus lucublandus*, 1 *Anisodactylus*, and 1 other carabid—items which formed 72 per cent of the stomach contents.

It must be admitted that in its fondness for terrestrial carabids the starling does some harm by consuming useful forms, but a study of the above data shows that only a small part of the Carabidæ eaten are of the decidedly beneficial species.

The scarabæids, or lamellicorn beetles, follow the weevils and carabids in the quantity of food furnished the starling, 2.24 per cent coming from this source. Of these by far the most important are the May beetles (*Phyllophaga*, adults of the notorious white grubs), which furnish the bulk of the 2.24 per cent. Both adults and larvæ are eaten, the former more frequently. No less than 11 species of

this genus were identified in the food of the starling, and from 4 to 8 individuals were frequently found in a single stomach. One bird collected in June had eaten 12. Approximately 300 of the 2,301 adults had taken May beetles, most of them in May, when they formed 11.04 per cent of the food. Dung beetles of the genera *Aphodius* and *Atænius* were commonly eaten, and *Canthon* and *Onthophagus* less frequently. Investigations conducted in 1919 to determine the bird enemies of the recently imported Japanese beetle (*Popillia japonica*) revealed the fact that the starling preys also on this insect; 2 of 6 starlings collected at Riverton, N. J., in August, had fed on it.

The Staphylinidæ (rove beetles), Chrysomelidæ (leaf beetles), Elateridæ (click beetles), Tenebrionidæ (darkling beetles), and others were taken in varying numbers. Most of these are small forms, and a considerable number could be destroyed without appreciably affecting the various percentages. Among the beetles of these families which were frequently eaten were many of economic interest, a few of which are here mentioned. *Drasterius elegans*, the larva of which is a wireworm that feeds on the roots of corn and other grains, had been eaten by 17 of the 2,301 adult starlings; *Agriotes mancus*, a species of similar habits, by 4; and *Colaspis brunnea*, a small leaf beetle that attacks beans, strawberries, and other cultivated plants, by 56.

Near Medford, N. J., it was stated that starlings had been seen working through a potato patch picking up potato beetles. Corroborative evidence was lent to this observation by finding the potato beetle (*Leptinotarsa decemlineata*) in the stomachs of 24 of 2,301 adult starlings and in 15 of 325 nestlings. Several birds had taken 4 individuals, while two nestlings had been fed 6 and 7, respectively. Many other chrysomelids, all of which are more or less harmful, are included in the food of the starling, the genera *Typophorus*, *Nodonota*, *Zygogramma*, *Calligrapha*, *Gallerucella*, *Oedionychis*, and *Chaetocnema* appearing regularly, though in small numbers.

The only darkling beetle taken in numbers was *Opatrinus notus*, found in the stomachs of 82 adults. Aside from these, a long list of other beetles, a few beneficial but most of them injurious, were identified in small numbers. On the whole, it may be said that the evidence obtained by a study of the starling's destruction of Coleoptera is overwhelmingly in the bird's favor.

ORTHOPTERA (Grasshoppers, Crickets, and Locusts).

While grasshoppers are not the serious pest in the Eastern States that they sometimes become west of the Mississippi, they nevertheless exact a certain annual toil from crops. A conservative estimate

of the annual loss in this country due to the grasshoppers is \$50,000,000.⁹ This would be much greater were it not for the controlling influence of insectivorous birds. Some of these, among which may be placed the starling, secure practically all of their insect food during September and October from this source, stopping thereby the depredations of millions of these insects and preventing the future development of countless millions more.

Orthoptera, among which the shorthorned grasshoppers (Acrididæ) and crickets (Gryllidæ) predominated, constituted 12.41 per cent of the annual food of the adult starlings examined. August to November, inclusive, are the months of greatest consumption, the percentages being 22.30, 30.75, 38.95, and 38.26, respectively. December and January are represented by 4.76 and 4.42 per cent, while from February to July few Orthoptera are secured, a fact quite logically explained by the life history of the insect. The extent to which the adult starling resorts to this food is shown by the fact that of the 2,301 stomachs examined over 800 contained the remains of Orthoptera, and during the height of the grasshopper season, from August to November, inclusive, 577 of 772 birds had fed on them.

When hay fields are being cut and raked in the latter part of August and early in September, flocks of juvenile starlings secure practically all their sustenance from these insects, supplemented with wild black cherries (*Prunus serotina*) and elderberries (*Sambucus canadensis*). Of a series of 20 birds collected in one hayfield near West Englewood, N. J., 16 had fed on Orthoptera, including acridids and crickets of the genera *Gryllus* and *Nemobius*. Still more remarkable is a series of 138 stomachs collected from September 20 to September 28 in the vicinity of Freehold, N. J.: All but 9 of these contained grasshoppers or crickets, and in bulk the insects formed 24 per cent of the food. That Orthoptera are abundant and sought for faithfully in the cool days of October is shown by a series of 11 starlings secured near Meriden, Conn.: These insects had supplied food for all of these birds and formed the sole content of 5 stomachs, and in bulk formed over 85 per cent of the total food taken. These 11 birds had destroyed no less than 40 grasshoppers, 77 crickets, and 1 locustid; 24 of 25 starlings secured in the vicinity of Meriden, Conn., in November, had also subsisted on Orthoptera to the extent of over 58 per cent of their food. In the stomachs of 6 of these, Orthoptera formed over 90 per cent of the contents.

Individual stomachs frequently contained surprisingly large numbers of crickets and grasshoppers. Inasmuch as information on this point is secured usually by counting the jaws of these insects, it often

⁹ Marlatt, C. L., The Food Bill of Destructive Insects of the United States, Reclamation Record, vol. VIII, no. 9, p. 427, September, 1917.

happens that the undigested remains of previous meals are recorded, but from the rapidity of digestion observed in other passerine birds, it seems highly probable that all particles of a starling's meal will have either been digested or passed on to the intestines in the course of a few hours. With this fact in mind, the significance of the following data may be appreciated:

A juvenile bird secured in September had eaten 7 short-horned grasshoppers (*Acrididæ*), 1 field cricket (*Gryllus*), and no less than 47 small striped ground crickets (*Nemobius*); a second bird from the same flock had taken 5 grasshoppers, 2 field crickets, and 47 small striped ground crickets; and a third, 6 grasshoppers, 1 locustid (*Xiphidium*), 1 field cricket, and 42 small striped ground crickets. In 19 other stomachs the last-named insect numbered 20 or more. Even the larger acridids were at times taken in quantity: A starling collected on September 2 had consumed 22, along with a locustid. Another had taken 16 acridids, 3 locustids, and 2 field crickets. A third ate 13 acridids, 3 locustids, 2 field crickets, and 1 small striped ground cricket.

Among the grasshoppers eaten by starlings were the red-legged locust (*Melanoplus femur-rubrum*), the green-striped locust (*Chortophaga viridifasciata*), and a number of the small grouse locusts (*Tettiginæ*). Besides the field cricket (*Gryllus pennsylvanicus*) and the small striped ground cricket (*Nemobius fasciatus*), a single specimen of the mole cricket (*Gryllotalpa borealis*) was taken. Additional related species were also eaten by nestling starlings, a discussion of whose relation to Orthoptera is presented on page 42.

LEPIDOPTERA (Mainly Caterpillars).

Lepidopterous remains in the food of the starling are composed almost entirely of the larvæ, or caterpillars, the greater part being consumed by nestlings (see p. 41). In the stomachs of adults these insects constituted 6.04 per cent of the yearly food. May and June are the months of greatest consumption, when such food forms 13.97 and 20.56 per cent, respectively, of the total. In September caterpillars formed less than 1 per cent (0.83) of the diet, while the remaining months of the year are represented with quantities varying from 1.04 per cent to 5.69 per cent of the food.

Of the 2,301 stomachs of adult starlings examined, 538 contained the remains of caterpillars; 20 contained pupæ; and 30, adult Lepidoptera. In June, the height of the caterpillar season, over half (115 of 205) of the adult birds used in this investigation had fed on Lepidoptera in one form or another, while in the preceding month 81 of 133 had taken such food.

Conspicuous among those birds which had fed extensively on caterpillars is a series of 31 adults collected in the middle of June,

near Flemington, N. J. Only one had failed to eat such food, which on the average formed 27.8 per cent of the bulk. In point of numbers, a starling collected at New Haven, Conn., takes the honors. In this bird's stomach were the remains of no less than 40 caterpillars, which formed 98 per cent of the food.

The terrestrial feeding habits of the starling limit the variety of caterpillars eaten, but this very restriction has permitted the bird to distinguish itself as a most effective enemy of that notorious pest, the cutworm. While caterpillar remains are not the most satisfactory items for identification in stomach contents and only occasionally are in condition for specific determination, the material in fully two-thirds of the starling stomachs could be referred with a fair degree of certainty to the family Noctuidæ.

Corroborative of what stomach examination has revealed is a bit of testimony secured from field observations on a farm at Adelphia, N. J., where starlings were observed doing exceptionally good work on the army worm. A rather heavy infestation of this insect had resulted in considerable damage, when a large flock of juvenile starlings started to feed regularly in the infested area; within a few days the worms had practically disappeared from those fields.

That other terrestrial caterpillars may find an enemy in the starling is recorded by an observer near Bloomfield, N. J., who, in the fall of 1915, witnessed starlings feeding on the larvæ of the cabbage butterfly.

In only a few instances were hairy or spiny caterpillars found in stomachs of adults. Among these were the American tent caterpillar (*Malacosoma americana*), an arctiid, and a "silver spot" (*Argynnis cybele*). One reason for not finding more spiny or hairy caterpillars may be explained by an incident observed at Norwalk, Conn., where a starling was seen to eat a tent caterpillar much after the fashion of the Baltimore oriole, by forcing out the soft parts and leaving the hairy skin hanging on the limb.

MISCELLANEOUS INSECTS.

Of other orders of insects from which starlings secure part of their sustenance, Hymenoptera, including bees, wasps, and ants, is best represented. This is of little importance, however, as the average monthly percentage is only 1.75, a great part of which is composed of ants. Most of this food is consumed during the summer, the monthly percentages from April to October inclusive being as follows: 1.11, 3.33, 3.41, 2.56, 2.14, 2.49, and 3.79. None of the late fall, winter, or early spring months were represented by as much as 1 per cent.

Connected with the capture of Hymenoptera is one of the oddest activities of the starling. While primarily terrestrial feeders, soon after the first of August young starlings were seen catching insects on

the wing, much after the fashion of true flycatchers. From a perch on a dead upper limb the birds would spy insects several yards away, fly out, and dexterously capture them. Later, after the first of October, starlings changed their tactics, adopting methods similar to those of swallows or martins in securing flying insects. The best illustration of these activities was furnished in northern New Jersey on a calm day above a warm, sunlit meadow. Here a dozen or more starlings were sailing about and capturing insects at a height of about a hundred feet from the ground. Under such conditions one not acquainted with the starling would certainly have mistaken the birds for martins, for, combined with a form which is quite similar, was this flight evolution, which imitated the martins perfectly.

Many ants in the winged stage are captured by starlings in their aerial evolutions, some are picked up on the ground, and others are secured from the branches of trees. On September 5 a number of juvenile starlings were noted diligently searching for and picking up food from the upper branches of a spruce. To some extent their actions imitated those of chickadees or warblers, though they were not so sprightly. One of these birds was collected and its stomach found to be filled with ants.

Ants of the genus *Myrmica* are most frequently eaten by the starlings. *Lasius*, *Formica*, and *Aphænogaster* also are taken. Beneficial ichneumonoid Hymenoptera were found in over 75 of the 2,301 stomachs of adults, but in most cases only a single insect each. The infrequent occurrence of bees and wasps in the food also indicates that they, as well as the ichneumons, are picked up here and there, no special effort being made by the starling to secure them.

Hemiptera, true bugs, form only an unimportant part (less than 1 per cent) of the food of the starling. March is the month of greatest consumption, due mainly to the quantity of soldier bugs (Pentatomidæ) eaten, these offensively odored insects forming over 2.5 per cent of the food in this month. As both predacious and plant-feeding forms are found among these insects, the result of an indiscriminate feeding on soldier bugs must be construed as neutral in its effect. In fact, this same construction may be placed on all the Hemiptera eaten by starlings. Among the plant feeders were found the chinch bug (*Blissus leucopterus*), the squash bug (*Anasa tristis*), and the tarnished plant-bug (*Lygus pratensis*); and among the predacious forms, the assassin bug (*Sinea diadema* and *Melanolestes picipes*).

Diptera (flies and their larvæ) were present in only a limited number of stomachs and formed a little more than 0.5 per cent of the annual food. Much of this material is secured about garbage heaps and in the neighborhood of cattle, with which starlings are familiar associates. The birds have been seen picking flies from the legs of

cows and in a few instances actually alighting upon their backs with the apparent intent of catching flies. In pastures starlings secure maggots by visiting partially dried cow droppings, which they thoroughly riddle by puncturing with their bills. As this material dries it becomes pulverized and scattered over several square feet of surface. Under such treatment dipterous larvæ not actually eaten by the birds soon die for want of moisture.

MILLIPEDS.

So far as known, no other bird in this country equals the starling in the destruction of millipeds. These creatures form 11.71 per cent of the adult bird's yearly diet. In April they amount to 54.69 per cent; in May, 42.19 per cent; and in June, 23.66 per cent; and, after a falling off in the later summer months, they again rise to 7.64 per cent in October. The fact that in April 119 adult birds of 132 examined, in May 133 of 140, and in June 146 of 215, had fed on millipeds, furnishes an idea of the persistence with which starlings search for such food in spring and early summer. Fifteen of the birds collected in April had taken nothing else, and 14 others had secured over nine-tenths of their food from millipeds.

At present the economic status of millipeds in this country is not fully understood. Were the theory accepted that was generally entertained a few years ago that millipeds feed entirely on decaying vegetable matter, the starling's destruction of them would have to be construed of neutral effect. In England, however, millipeds of the same and closely related genera are decidedly destructive in gardens, and recent investigations have shown that they have similar habits in this country. Damage to beans, strawberries, melons, cucumbers, radishes, and potatoes has been attributed to one species (*Julus cæruleocinctus*) which is a favorite food item of the starling. The full significance of the starling's destruction of millipeds will be known only when the habits of these animals are better understood. Whether their status be neutral or injurious, in feeding on them the starling secures a much needed supply of animal food and at the same time does not draw materially from the supply of other birds, few of which have shown a preference for millipeds.

SPIDERS.

Spiders hold by no means the attraction for adult starlings that they do for the nestlings (see p. 43). Of the 2,301 stomachs examined, 480 contained spiders, which formed 1.48 per cent of the annual diet. In only one month did they constitute over 3 per cent of the food; in December, 17 of 44 birds had eaten spiders to the extent of 3.48 per cent of their food. Most of the arachnids eaten were wolf spiders (Lycosidæ), which are terrestrial in habits and generally

considered less distinctly beneficial than some of the other spiders which secure many of the flying insect pests in their silken nets.

MOLLUSKS.

In contrast with the large numbers of injurious slugs secured by the starling in some parts of its native home, particularly in England, is the quantity and character of the molluscan food of the bird in this country. Mollusks of various kinds, but mainly land snails, formed less than 1 per cent (0.94) of its annual food. A large part of this was secured in October, when 20 of the 108 birds examined had fed on it. These 20 birds were collected along the Connecticut shore, the snails eaten being mainly of the genus *Melampus*. In no case was a land slug detected.

MISCELLANEOUS ANIMAL FOOD.

The remains of earthworms, fragments of a crab, a few beach fleas (*Orchestia*), sowbugs (*Porcellio*), bones of a salamander (in one stomach), and bits of fat, suet, or cartilage, secured apparently from garbage dumps or at the winter feeding stations erected to attract birds, fill out the varied animal diet of the starling. All these items combined form only 1.32 per cent of the bird's yearly food, and most of them are secured during the winter and early spring months. That the bird's desire for animal food is in a measure satisfied as soon as the winter's snow disappears in March is revealed by the quantity of animal garbage consumed in that month, when it forms about 8 per cent of the diet. The main grievance against the starling for its consumption of the foregoing food items is entertained by bird lovers whose generous supplies of suet put out for native birds soon disappear when discovered by a flock of starlings.

VEGETABLE FOOD OF ADULTS.

CHERRIES.

One of the most frequent complaints against the starling is in connection with its fondness for cherries. From the economic standpoint, this is undoubtedly its most objectionable habit. The cherry is cultivated on a commercial scale in only a part of the starling's present range, but is grown as a home fruit, a tree or two about the dooryard, throughout most of its habitat. This condition renders the crop peculiarly susceptible to attack by robins and starlings, the two most abundant fruit-eating birds of the region.

In 1915, on a farm near Closter, N. J., trees that should have produced \$50 to \$60 worth of cherries yielded only \$10 worth, a loss largely due to starlings. At Bristol, Conn., a flock of about 300 starlings entirely stripped a single tree of its 1916 crop in less than 15 minutes. At Rowayton, Conn., six cherry trees were entirely stripped

of their fruit by robins and starlings in 1916. These are but examples of the many instances which came to the notice of the writers while in the field of birds taking part or all of the fruit from isolated trees.

Of the 2,301 stomachs of adult starlings examined, 169 contained cultivated cherries, which formed 2.66 per cent of the yearly food of the species. Early cherries in June were eaten by 67 of the 215 birds examined, while late varieties in July furnished food for 91 of 375. In June, this fruit formed 17.01 per cent of the adult starling's food, and in July, 14.92 per cent.

Without attempting to mitigate the offense of the starling by calling attention to another notorious cherry thief, some idea of the extent of the starling's activities may be gained by comparing its food habits with those of the robin. From the examination of 1,236 stomachs of robins, it has been found that this species feeds on cultivated fruit to the extent of 8.63 per cent of its annual food, as against 4.41 for the starling. During the months of June and July, the robins obtained 24.58 per cent and 22.71 per cent, respectively, of their food from cultivated cherries, quantities half again as great as those consumed by starlings in the same months. Another matter of note is the number of complaints against the robin as compared with the number made against the starling for the same offense. This is in part due to the different methods of feeding employed by the two species. The robin is universally distributed and feeds in loose flocks, individuals of which may be found maintaining an almost uninterrupted procession to and from some favorite cherry tree for entire days. At no time will a great number of the birds be found in a tree, but the slow drain on the cherry crop is constant through all hours of daylight. The birds are frequently feeding young at this time and are carrying cherries to them. On the other hand, starlings, the young of which are the chief offenders; frequently gather in large flocks, and, swooping down on a single tree, completely strip it of fruit while other trees in the neighborhood may remain untouched. As a result, while practically every cherry grower complains of the robin, those who suffer from the more spectacular raids of the starling are much more bitter in their complaints. This condition led to an investigation at several points in Connecticut to determine the relative damage caused by several cherry-eating species, and trees were watched to determine as far as possible the number of birds eating the fruit. The summary of the data obtained is presented in Table I.

TABLE I.—*Comparison of depredations by various species of birds on cherry trees in Connecticut.*

Date and length of time spent at each tree.	Number of birds that came to eat cherries.											
	Star- lings.	Rob- ins.	Cat- birds	Pur- ple grack- les.	Rose breast- ed. gros- beaks.	Eng- lish spar- rows.	Balti- more ori- oles.	Cow- birds.	Red- winged black- birds.	Blue jays.	Chip- ping spar- rows.	Total birds.
June 26, 2 hrs., 15 mins.	12	17	7	1	2	1	2					42
June 26, 1 hr., 15 mins.	19	17		8				1	1			46
June 27, 45 mins.		42	9				1					52
June 27, 3 hrs.	8	14		5	2	1		1				31
June 27, 10 mins.		15	2									17
June 29, 3 hrs., 30 mins.	50	4		4								58
July 4, 10 mins.	1	50		1								52
July 5, 15 mins.	20	4										24
July 10, 2 hrs.	3	24	4	3	2	3				4	5	48
Totals.....	113	187	22	22	6	5	3	2	1	4	5	370
Percentage.....	30.54	50.55	5.94	5.94	1.63	1.35	0.81	0.54	0.27	1.08	1.35	.....

On examination of this table it is found that about half the birds feeding on cherries were robins, less than a third were starlings, and the others were of various species, none numerous enough to be of any consequence. This interesting bit of evidence is confirmed by stomach analyses of robins and starlings. The stomachs of 11 robins, collected while feeding in cherry trees, contained 10.27 per cent animal matter and 89.73 vegetable matter, of which 85.73 per cent was cultivated cherries. Forty-nine starlings, obtained under the same circumstances, had fed on animal matter to the extent of 58.12 per cent of their food; and vegetable matter, 41.88 per cent; cultivated cherries formed 36.72 per cent of the total.

It was the experience of the writers that shooting a few starlings from cherry trees soon discouraged the survivors so effectually that they seldom returned. The robins, on the other hand, were exceedingly bold and paid no attention to any frightening devices placed in the trees or to shooting. Frequently a starling or a robin was shot from a tree without alarming other robins feeding.

From the above data it will be seen that the starling eats fewer cherries, both individually and as a species, than the robin, although his attacks are much more conspicuous. According to most observers, the robin, as well as the starling, increased considerably in numbers in the decade following 1910 throughout the area covered by this investigation, and both species are undoubtedly responsible for the increasing difficulties of cherry culture. Both species have habits to recommend them on economic grounds, with the starling in the more favorable position on account of its smaller consumption of fruit and much larger consumption of noxious insects.¹⁰

¹⁰ For a detailed record of the robin's food, see Food of the Robins and Bluebirds of the United States, by F. E. L. Beal, Bull. 171, U. S. Dept. of Agr., pp. 2-15, 1915.

BERRIES.

Some complaints of damage to strawberries have been made, but the investigation failed to reveal extensive depredations by the starling. A few farmers in New Jersey stated that the birds occasionally ate berries, and one farmer in Connecticut shot 9 birds out of a flock that started in on his berry patch. At the discharge of the gun the starlings flew away and did not return. Little complaint was made of damage to blackberries or raspberries, and as in most places wild varieties are more abundant than cultivated ones there is little danger of the starling doing much damage to such fruits.

APPLES.

Field work conducted in September and October was devoted largely to investigating complaints about starlings damaging late fruits, particularly apples. Extensive inquiries were made among the farmers in those sections of New Jersey and Connecticut where the starling was common, and no opportunity of collecting in orchards was overlooked. Considering the time and attention given to this phase of the subject, it must be stated at the outset that positive incriminating evidence against the starling secured from personal observation and stomach analysis is small.

Of the 2,301 stomachs of adult starlings examined, 45 contained the pulp or skin of apples. Only 22 of the 45, however, were among those collected in September and October, the remainder having been taken in winter and early spring, when the fruit eaten was manifestly waste, left on the trees or fallen to the ground. In bulk, cultivated fruit other than cherries, of which a large part was apples, formed 1.75 per cent of the total annual food. In September it amounted to 2.19 per cent, and in October, 0.38 per cent. A large part of the stomachs in which apples occurred were secured in small orchards in the vicinity of Adelphia, Monmouth County, N. J., whence several complaints had come.

On September 22, 1916, a flock of 200 or more juvenile starlings were seen feeding on apples in a small orchard of middle-aged trees near Adelphia. Only a few appeared to be eating the fruit, the remainder being engaged in singing or preening their feathers. Afterwards the trees were inspected. The apples in the central top of the trees were the ones sampled, and in many instances it was noted that the birds had gone back to feed on fruit pecked open on previous occasions. An opening an inch or two in diameter was pecked in the skin and then a large portion of the pulp was eaten out through this break (see Pl. IV, fig. 2).

On the following day a flock of birds was observed at work in a tree of russet apples on a neighboring farm. Subsequent inspection of

the fruit in the tree top showed that probably not over 5 per cent of the apples had been pecked.

At Glen Cove, N. Y., a flock of about 100 starlings was noted attacking the fruit in one tree of an orchard where damage had been reported in previous years. On this occasion about one apple in every five was damaged. The owner of this orchard, who was a keen observer of birds, asserted that starlings had ruined 10 per cent of his crop in 1915. Of 30 barrels picked, 3 had to be discarded.

Isolated apple trees, especially those standing in the middle of hay fields where flocks of juvenile birds are accustomed to feed on insects, are likely to have their fruit damaged. Such a tree at East Norwalk, Conn., had nearly every apple pecked, and a similar one was found near Farmington, N. J., but in neither case was the crop of any value, and it was never harvested.

Late-maturing varieties are more likely to be attacked by starlings than those ripening at the height of the apple season, owing possibly to the fact that the supply of wild fruit, as wild black cherry (*Prunus serotina*) and sour gum (*Nyssa sylvatica*), has been materially depleted by that time. The starling's taste for apples, combined with its flocking habit, presents a condition which should be watched because of the bird's capacity for damage. At present, however, the aggregate damage done is not great. On no farm given largely to fruit-raising, where the trees were thrifty and well kept, was injury to apples observed or reported. The number of extensive fruit raisers in areas of starling abundance who had no complaint to make is legion. At present the bulk of the damage is confined to old orchards and isolated trees. In many cases the damaged fruit is on trees sadly neglected and of inferior quality.

PEARS AND PEACHES.

In only three stomachs was the pulp of pears found (twice in September and once in January) and field work also yielded little positive evidence that the starling damages this fruit. One report from Ambler, Pa., asserted that in 1915 starlings had ruined a whole tree of pears; additional reports of damage came from Bloomfield, N. J., but in none of these was the loss great. Injury to peaches is also slight—one of the more specific reports came from a farmer of Warren, R. I., who stated that in 1914 he had lost about 2 per cent of his crop on account of starlings.

GRAPES.

To a limited extent starlings have exhibited in this country the same habits that have made them unpopular during late summer in the vineyards of France. Testimony on this point comes entirely

from outside observers. No grapes were found in the stomachs examined and no damage of this kind was observed by representatives of the Biological Survey. A farmer in the Brookdale section north of Bloomfield, N. J., reported that starlings had severely damaged grapes on a small arbor on his farm, and similar complaints came from a number of farmers in the neighboring sections about Richfield, N. J. No damage was reported in the extensive vineyards about Vineland, in southern New Jersey, but as the starling was not yet abundant there this can not be looked upon as an indication of its innocence. As in the case of apples, the injury to grapes is at present trivial in the aggregate and is practically nil in extensive grape-raising sections, but from the starling's reputation in some parts of Europe it will bear watching in these surroundings.

CORN.

Probably the losses to crops most keenly felt by the farmers living in the intensively cultivated area in northeastern New Jersey, about the cities of Hackensack, Bloomfield, Elizabeth, and Newark, are those inflicted by grain-eating birds on sweet corn. During July and August mixed flocks, sometimes numbering into the thousands, of grackles, red-winged blackbirds, cowbirds, and, in recent years, starlings, roam through the country, securing the bulk of their sustenance from cornfields. Sweet corn, just ready for market, is torn open, some of the juicy kernels eaten, and the ear either rendered unsalable or its market value considerably reduced. In the aggregate such losses are very great and in the eyes of the farmers of northeastern New Jersey, the starling is to blame for a large share of the damage. However, as in the case of men, who are often judged by their company, the starling has been accused of deeds perpetrated largely by the species with which it associates. Not only were these birds generally charged with eating as much corn as the grackles and red-wings, an assumption which has been disproved, but many farmers were uncertain of their identification, with the result that flocks of juvenile red-wings were often called starlings and their depredations charged against the latter.

Of the total of 2,301 adult starling stomachs examined, 52 contained corn, and this formed less than 1 per cent (0.77) of their yearly food. Of the 1,059 starlings collected during the ripening and harvesting season of July, August, September, and October, only 14 had fed on corn, which constituted only 0.2 per cent of their food during this period. In the planting and sprouting season of April and May, 6 of 249 adult starlings had fed on corn, which formed 0.52 per cent of the food. By far the largest part of the corn eaten by starlings is waste grain secured in winter and early spring. In Jan-

uary corn forms 1.54 per cent of the diet, in February 2.03 per cent; and in March 3.49 per cent, the largest proportion recorded for any month.

While the result of the examination of so large and thoroughly representative a series of stomachs refutes all the extreme accusations against the starling as a corn eater, a discussion of field observations made in this connection will emphasize this point and show where the blame lies. A number of complaints had come from the vicinity of West Englewood, N. J. This section was visited in the middle of August, when a survey of some of the most seriously damaged fields was made. Much of the sweet corn had been harvested, but there were still some fields of the late varieties in which birds were at work, and in patches of early corn saved for seed a record of their activities earlier in the season was found. A farmer of West Englewood, who is familiar with the starling, reported that starlings joined with red-wings in damaging his crop. A census of part of a seed patch on his farm showed that of 863 ears of sweet corn examined, 231 had been injured by birds, a percentage of over 26. On another farm at Teaneck, N. J., fully 33 per cent of the seed corn had been damaged. Examination of a field at River Edge, N. J., revealed 100 damaged ears out of 297 inspected. Several other seed patches in this general vicinity were even more seriously damaged, in one case on several hundred stalks scarcely a single ear being left unmutilated.

An insight of what species were doing such work, and were probably also to blame for most of the injury to seed patches earlier, was secured on a farm near West Englewood, N. J., on August 23. Here a mixed flock of red-wings and grackles were feeding on a field of sweet corn in which pickers were at work. The field was large and the birds would feed in parts distant from the pickers. The owner asserted that already he had 2,500 ears damaged, and that while many of these were still salable they brought reduced prices, only 50 to 75 cents per 100 being paid instead of \$2, the market value of perfect ears at that time. A careful watch for several days in this and surrounding fields failed to disclose a single starling feeding there, while the red-wings and grackles spent little time elsewhere. Juvenile red-wings were generally considered starlings by the farmers of this locality.

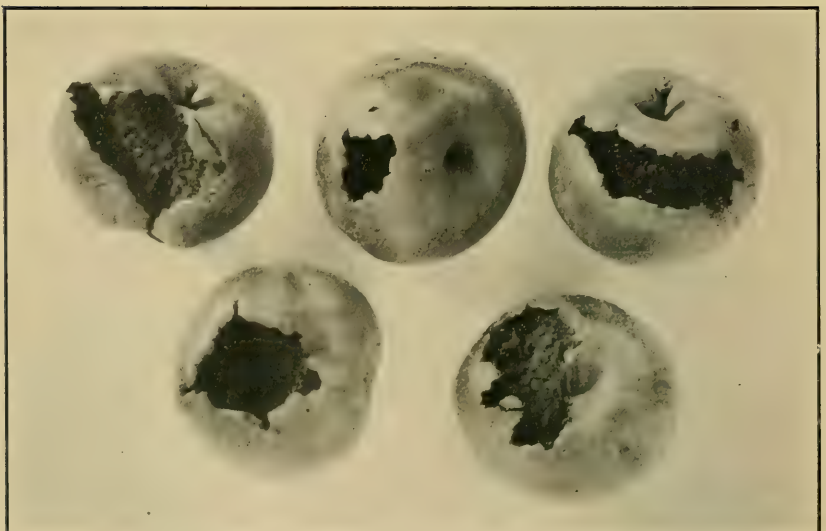
On a few occasions the investigators observed starlings actually tearing down the husks of corn and feeding on the kernels, but in no case were starlings in large-sized flocks seen inflicting serious damage. Positive incriminating testimony has come, however, from other observers. A reliable observer of Glastonbury, Conn., has seen flocks, composed entirely of starlings, doing damage to the corn crop in two fields to the extent of 25 per cent and 10 per cent, respec-



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FIG. 1.—SWEET CORN DAMAGED BY MIXED FLOCKS OF STARLINGS AND RED-WINGED BLACKBIRDS.

Only a small portion of the corn in this patch, saved for seed, was harvested, owing to the depredations of birds. Red-winged blackbirds were chiefly to blame.



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FIG. 2.—RUSSET APPLES DAMAGED BY STARLINGS.

These apples were from the tops of trees in an old orchard near Adelphia, N. J. Some of the damaged fruit showed evidence that the birds returned to an apple opened on a previous visit.

tively. A resident of Rochelle Park, N. J., who is well acquainted with the starling, asserted that for several years past these birds had taken toll from his fields. Others also have seen the starlings, while part of a mixed flock, actually feeding on the ears of corn.

Damage to field corn was reported less frequently than to sweet corn, and the reports were subject to the same errors of identification of birds. On one farm west of West Caldwell, N. J., the starling was bitterly criticized for its work on a 2 to 3 acre patch. Some time was spent observing the bird visitants to this field, and it was found that English sparrows were busily engaged in tearing down the husks for an inch or two, as far as their strength allowed, and eating the terminal kernels.

In the vicinity of Freehold, N. J., where a large starling-grackle roost was located, flocks of starlings were common about the middle of September in the near-by cornfields. Many of the birds would perch on the top of the cornstalks and sing, fully as many would be on the ground apparently in search of insects, and a few could be noted pecking the ends of the ears. One field of several acres appeared to be a favorite resort, and earlier in the year, when the corn was in the milk, damage had been done there. The proprietor asserted that early in August, when most of the corn was damaged, starlings in a large flock visited his field twice daily, morning and evening. A count in part of the field showed that of the 522 ears examined 136, or more than 26 per cent, had been visited by birds. Over half the opened ears, however, showed the unmistakable track of the corn worm. It is highly probable that the birds often devoured the insects they exposed in tearing down the husk. Another field, northwest of Freehold, which was visited by large flocks of starlings in early morning and late afternoon, was carefully inspected, and very little bird work was found, but a heavy infestation of corn worms had severely damaged the crop.

A comparison of the food habits of the starlings and grackles occupying the Freehold roost in September was obtained from the examination of material collected there. Six of the 116 starlings had fed on corn, and in the stomach of one, this grain formed 94 per cent of the contents, in another 60 per cent, in a third 12 per cent, and in the remaining three only 1 per cent each, making an average percentage of about 1.5 for the lot. Twenty of the 27 grackles shot at the same roost had fed on corn, and in 11 this constituted the entire stomach contents. The corn consumed by the 27 grackles formed over 76 per cent of their food. With this was over 11 per cent of other grain, principally oats.

To a limited extent starlings were accused of pulling sprouting corn, both sweet and field varieties. At Mendham, N. J., it was

reported that starlings had pulled nearly an acre of corn in one field, and at Spring House, Pa., it was asserted that starlings had pulled corn so badly on a 10-acre field that it had to be replanted.

While laboratory examination shows that the starling is not an extensive feeder on ripening corn, field observation indicated that where local conditions are favorable, as in the vicinity of roosts, the birds may do damage. The aggregate loss to the corn crop which can be definitely attributed to the starling is not great. Many of the complaints against the starling have been based on a misidentification of the species—red-winged blackbirds and grackles being more frequently responsible. The aggregate loss to sprouting corn is trivial. The fact that starlings are easily frightened by gunfire and will shun an area after a day or two of shooting suggests effective preventive measures, which have not proved successful in the case of the other two species mentioned.

SMALL GRAIN.

The farmer has little need to fear the starling as a menace to small grains. Twenty of the 2,301 adult birds examined had fed on small grain, and of these 13 had eaten wheat, 6 oats, and 1 millet. In bulk this formed 0.39 per cent of the food, and fully half of this was eaten at a time of year when it manifestly must have been waste. The few complaints on this score were either so trivial in nature or so widely separated that the aggregate injury is not important. The complaints involved the picking up of newly sown oats, the "pulling" of sprouting oats, and feeding on ripened wheat and millet. At Sound Beach, Long Island, a flock of about 500 starlings was noted feeding in a millet patch, the owner of which claimed that the birds had eaten all the seed from a similar patch in the previous year and that it appeared as if they would repeat the performance.

GARDEN TRUCK.

From the impossibility of satisfactorily identifying such food items as chewed-up bits of lettuce and spinach leaves, tender pods of peas, pulp of tomatoes, etc., it is apparent that stomach examination does not satisfactorily determine the relation of the starling to garden truck. In no case were such items positively identified in stomachs, though reliable field observers have witnessed attacks on these and other products of the garden at odd times. The depredations are confined mainly to small city gardens, where the succulent green foods are readily accessible to an unusually large number of starlings. In intensively cultivated truck-crop areas, as in the Brookdale section, north of Bloomfield, N. J., similar conditions sometimes prevail.

An observer of Stratford, Conn., has witnessed starlings pecking holes in his tomatoes, and an extensive grower of tomatoes at Stratford asserted that of the first three crates of tomatoes picked in 1917 one had to be discarded, owing to the work of starlings. A farmer of Brookdale, N. J., has suffered losses to late tomatoes, and near-by growers complained that starlings scratched out seeds of radish, parsley, and spinach when these were sown under manure in winter and very early spring. Similar complaints were heard in Richfield, south of Paterson, N. J. At Demarest, N. J., a muskmelon patch was inspected after starlings had been at work pulling the young sprouts. Of about 15 hills of 3 or 4 plants each only 7 plants remained. On this same farm starlings took all of two plantings of onion sets in a small garden near the house. On a farm west of Oradell, N. J., sprouting lima beans shared the same fate, and in a small garden in Hackensack, N. J., 150 young lettuce plants were "pulled." A resident of Bay Shore, N. Y., had many of his green peas taken by starlings.

These instances are typical of the damage starlings may do to gardens. In the main their work is confined to small plots, and the losses are most keenly felt by the city dweller who has painstakingly tilled and planted a few square yards of soil. In the extensive truck-crop sections the aggregate damage of this kind is not great.

WILD FRUIT.

The starling is essentially an insect-eating and fruit-eating bird, and wild fruits form the largest single item in its yearly food (23.86 per cent). Both the quantity and variety naturally change with the season. In May, when millipeds, beetles, and other insects are abundant, wild fruit disappears entirely from the diet. The first half of June sees little change in the food habits, but as cherries begin to ripen the birds begin to flavor their diet with fruit, wild as well as cultivated; and mulberries (*Morus rubra*) and June berries (*Amelanchier*) form practically all of the 1.1 per cent of wild fruit taken in this month. In July, with the ripening of red and white mulberries, the starlings enter on a veritable orgy of fruit eating, which continues until well into October, as one species of fruit after another ripens. In July, 35.82 per cent of the food consists of wild fruit, practically all of which is mulberries and blackberries. A rather open country, with occasional groups or single trees of mulberry or wild cherry, furnishes an ideal feeding ground for the flocks of young starlings which wander over the country during the summer and fall months.

Early in August the chokecherry (*Prunus virginiana*), and later in the month the black cherry (*Prunus serotina*) and the elderberry (*Sambucus canadensis*), supply the bulk of the 40.88 per cent which

represents the fruit consumption for this month. Other fruits taken in small quantities give variety even in the fruit portion of the diet.

The 39.51 per cent of fruit consumed in September consists principally of the black cherry, which holds over from the preceding month, sour-gum berries (*Nyssa sylvatica*), Virginia creeper (*Psedera quinquefolia*), elderberry (*Sambucus*) and small quantities of many other fruits which ripen at this season.

By the first week in October many of the juicy berries are gone, although Virginia creeper and sour gum still furnish a considerable supply. These, however, soon disappear, and other sources of food are found in the immense number of grasshoppers present at this season and in bayberries (*Myrica carolinensis*). These dry, hard berries furnish the bulk of the 23.76 per cent of wild fruit found in the stomachs collected in this month, and supply a staple food throughout the winter.

Wild fruit enters into the winter food in the following percentages: November, 41.80; December, 36.44; January, 19.98; February, 32.90. In all four months practically the only fruits taken are the waxy bayberries and the seeds of the various species of *Rhus*, all of which are dry and hard, thinly covered with fruit pulp and skin. The starling apparently feeds on them only when unable to secure any other food. Whenever snow is off the ground the birds commence to search for insects and return to the sumac and bayberries only when compelled to do so by a fresh snowfall. In March, although there are few insects available, the feeding on wild fruit shows a decrease of over one-half, only 13.69 per cent of the month's food coming from this source. Garbage replaces it to a large extent, and it is apparent that the melting of the snow enables the birds to feed more on the ground and depend less on the hard berries on which they had so largely subsisted during the winter.

April, with its increasing abundance of early insects and millipeds, shows a practical abandonment of fruit eating by the species. Only 0.34 per cent of the food for this month is fruit, and this consists of a few seeds of *Rhus* and *Myrica* which escaped the winter's gleaning and have been picked up one or two at a time by different birds.

During the five months from October to February the starling takes the seeds of poison ivy (*Rhus toxicodendron*) in quantities varying from 1.42 per cent in January to 7.77 per cent in December, and, while this item forms only 1.71 per cent of the annual food, it is of some economic importance. The seeds are eaten, as are all other berries of a similar nature, simply for the thin outer covering of pulp and skin, and the hard parts pass through the digestive tract or are regurgitated, their germinating qualities uninjured. The starling thus becomes an agent in their dissemination, but as the birds so often roost over city streets or in buildings, part of these seeds are

deposited in places where they can not grow. In the actual spread of this noxious weed, the starling is probably less responsible than many of our native birds, which scatter most of their regurgitated seeds where they have at least a fair chance for growth.

MISCELLANEOUS VEGETABLE FOOD.

Of the total annual food of the starling 13.57 per cent may be classed as miscellaneous vegetable matter. This consists almost entirely of refuse eaten during the winter months, as coffee grounds, orange seeds, beans, parings of various fruits and vegetables, and similar material commonly found on garbage piles. Mast and various grass and weed seeds are also present in insignificantly small quantities. Ragweed (*Ambrosia artemisiifolia*) and foxtail grass (*Chætochloa glauca*) were most commonly found, and as the starling habitually feeds in fields and pastures containing an abundance of these two weeds, it is not surprising that a few seeds are occasionally taken.

The garbage eaten has no economic significance, even so indirectly as the cutting down of the available food of native birds, as they seldom resort to such food.

FOOD OF NESTLINGS.

From an economic standpoint, the food habits of nestling passerine birds are, as a rule, more commendable than those of the adults, and when one considers that during the nestling period the young birds of many species outnumber the parents two to one, the importance of knowing what they are capable of doing is manifest. Then, too, it must be remembered that the food required for the young growing bird is vastly more than that needed for its parent. During the first few days of the nestling's life, especially, it consumes enormous quantities of food, estimated in the case of some species to be on each day a mass equal to its own weight. This demand for food, much of which consists of injurious insects, is greatest during May, June, and July, a time when growing crops are benefited most by a suppression of their insect enemies.

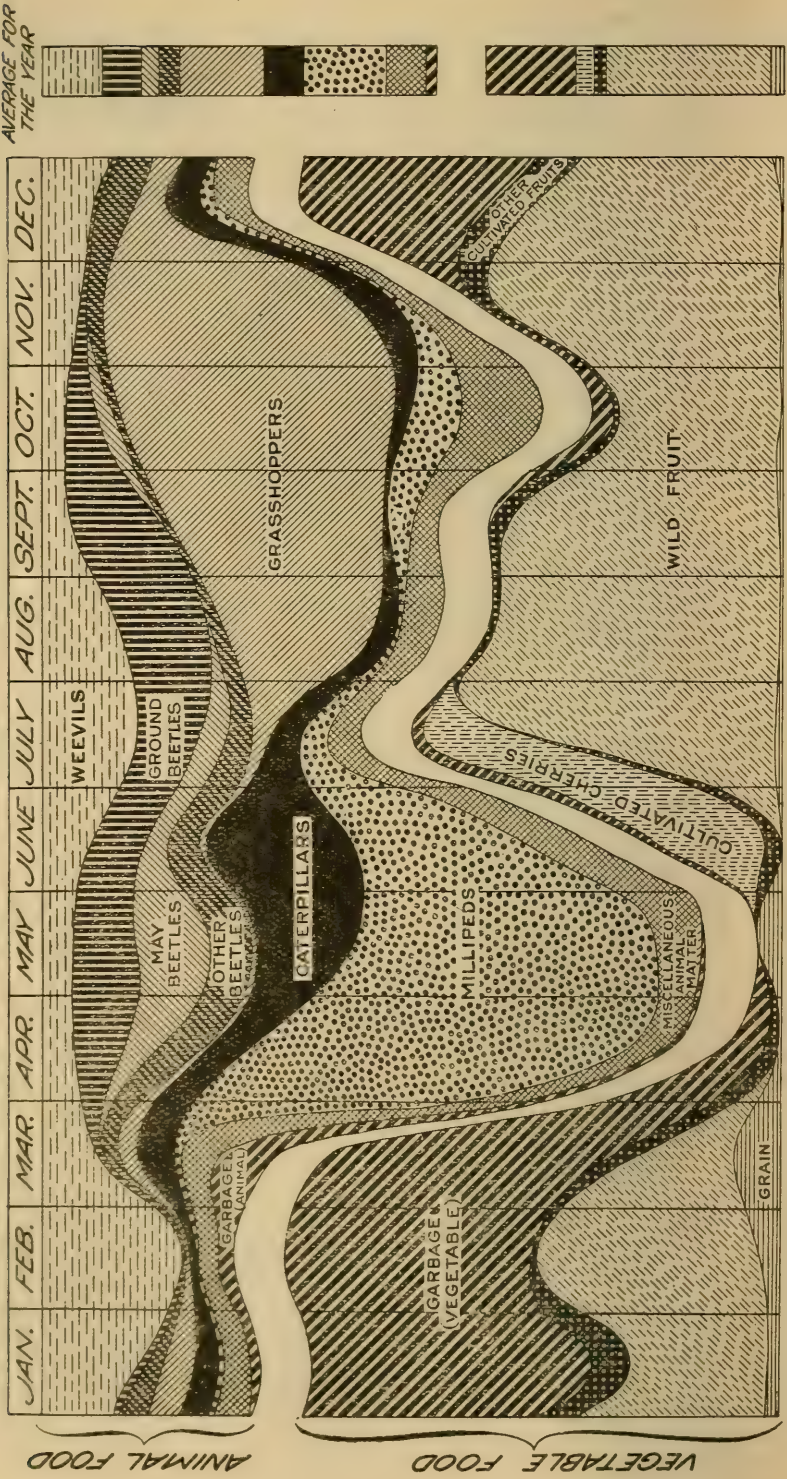


FIG. 2.—Chart of food of 2,157 adult starlings, showing the varying quantities of the principal items from month to month, and the relative monthly average of each item. In Table II, page 39, the same information is presented in percentages.

TABLE II.—*Monthly percentages of the various items in the food of adult starlings (see fig. 2).*

Kind of food.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Monthly averages.
Weevils.....	14.10	20.16	7.97	4.35	4.31	7.39	13.36	10.91	3.93	3.13	5.33	7.00	8.50
Ground beetles.....	1.23	0.42	1.07	7.31	8.76	7.96	9.11	13.02	12.93	4.56	1.16	1.12	5.71
May beetles.....	0.14	.....	0.27	4.52	11.04	3.28	4.08	0.45	0.38	2.60	0.10	0.05	2.24
Other beetles.....	2.27	0.49	2.39	6.55	6.23	4.56	3.70	1.76	0.75	1.15	2.27	5.54	3.14
Grasshoppers.....	4.42	0.55	2.61	1.59	0.84	1.24	2.77	22.30	30.75	38.95	38.26	4.76	12.41
Caterpillars.....	3.88	1.04	5.24	5.56	13.97	20.56	4.57	3.69	0.83	2.16	5.69	5.26	6.04
Millipeds.....	0.44	0.04	0.66	54.69	42.19	23.66	3.68	0.20	4.11	7.64	1.24	2.02	11.71
Miscellaneous animal matter ¹	3.91	3.07	6.23	5.26	6.98	10.80	5.71	5.56	3.56	11.83	3.01	5.05	5.93
Garbage (animal).....	1.69	2.40	8.15	1.39	0.63	0.32	0.35	0.32	.....	0.23	.....	0.36	1.32
Garbage (vegetable).....	40.56	35.97	41.25	6.76	4.58	1.04	1.49	0.34	0.54	3.61	.....	26.62	13.57
Cultivated cherries.....	.....	.....	.....	.....	.....	17.01	14.92	.....	.....	.....	.....	.....	2.66
Other cultivated fruits.....	5.84	0.66	2.87	0.76	.....	1.06	.....	0.50	2.19	0.38	0.96	5.78	1.75
Wild fruits.....	19.98	32.90	13.69	0.34	.....	1.12	35.82	40.88	39.57	23.76	41.80	36.44	23.86
Grain.....	1.54	2.30	7.60	0.92	0.47	.....	0.44	0.07	0.46	.....	0.18	.....	1.16

¹ Under this heading are included Hymenoptera, Hemiptera, Diptera, and other miscellaneous insects, spiders, and mollusks.

OBSERVATIONS FROM BLIND.

Few birds are more voracious than young starlings, and when there are from 4 to 6 to feed, it requires the most strenuous efforts of their naturally active parents to supply their constant needs. An insight into the feeding operations was obtained near Closter, N. J., by means of a blind, from which a nestful of 5 young starlings could be watched at close range. This blind was so placed that the opening made for observation was within 2 feet of the nest cavity. This was located about 6 feet from the ground in the hollow limb of an apple tree. In watching these birds, attempt was made to identify the food brought in and to determine the frequency of feeding.

Efforts at identification met with little success, as in no case could an item be specifically identified, even though much of the food was carried in plain view at the tip of the bill of the parent bird and often within 18 inches of the eyes of the observer. The alertness of the bird prevented more than a momentary glance at the food it carried. Such identifications as "cutworms," "earthworms," "grasshoppers," and "ground beetles" were the best that could be made under the circumstances; and then, since fully a third of the food of the starling is carried where it is partially or wholly concealed at the base of the bill or in the throat, this phase of the observations afforded few facts of value—very little compared with the detailed data secured from stomach examination. It was noted, however, that rainfall had a distinct effect on the character of food brought to the young. During showery weather or on days succeeding rainy nights large quantities of earthworms and cutworms were secured. The main source of this supply was a near-by garden. A low meadow was a favorite

feeding ground during drier weather, and it was here that the birds secured most of their beetle food.

Observations as to the frequency of feeding gave more satisfactory results. Although the starling is extremely cautious in its feeding operations, this characteristic was less pronounced in the pair used in this observation, owing to the fact that the nest was situated within a few feet of the crossing of two well-traveled roads, and frequently the parent birds would sit calmly in the tree while several vehicles and pedestrians would pass within 20 feet. Little concern was shown over the presence of the blind, but of the two birds the male was by far the more cautious and at times would be frightened away from the nest by some cause or other, thus delaying a feeding. It often happened that the female would make several feeding trips while the male was thus alarmed, and on one or two such occasions the female attacked her mate, after which he would obediently visit the nest and feed the young.

In nine days a total of 390 feedings were recorded, in 14 periods varying in length from 30 minutes to 4 hours and 41 minutes. One hundred and four of the feedings were by the male and 286 by the female. An average of one feeding every 6.1 minutes was maintained for the whole period of observation, 31 hours and 10 minutes. The highest rate was recorded on the morning of May 18, which was probably the seventh day of the nestlings' life. A feeding every 3.2 minutes was maintained for 4 hours and 41 minutes. The lowest rate, once every 11.7 minutes, occurred on May 25, the day before the young left the nest.

On the basis of one feeding every 6.1 minutes, and assuming that the young are fed 12 hours a day, which is conservative, there would be 118 feedings a day. As this brood left the nest on the sixteenth day, which is probably several days short of the normal nestling period of the starling, for the birds were disturbed considerably during the latter days of their nestling life, a total of 1,888 feedings would have been given to this brood of five, or 377.6 for each nestling. When it is borne in mind that the parent birds would often bring in three or four cutworms, earthworms, or grasshoppers, or an equal bulk of miscellaneous insect food, at a single trip, one may gain an idea of the quantity of food required to develop a brood of young starlings.

STOMACH EXAMINATION.

For detailed study of food items an excellent series of 325 stomachs of nestlings, collected in Connecticut, New York, and New Jersey during May, June, and July, was available. Sixteen of these, however, contained so little food that they could not be used in estimating percentages, leaving 309 for such purposes. Nestlings in all stages

of growth, from the blind, callow young of a day or two to the husky, energetic fledgling ready to leave the nest, are about equally represented, with the result that the percentages of the various food items may be considered to be fair averages for the entire nestling period. It is well known that as nestlings grow older there is a gradual change in food preferences. A discussion of the change of food habits in the growing nestlings, based on this material, grouped according to the age of the birds, will be found in Table III, on page 44.

ANIMAL FOOD.

Compared with the 338 stomachs of adult starlings collected in May and June, it is found that the percentage of animal matter eaten by nestlings is somewhat greater, 95.06 per cent in place of 82.36. By far the largest animal item consisted of caterpillars, which, along with a few moths and a cocoon or two, formed 38.21 per cent of the food of young starlings and were present in 274 of the 325 stomachs examined.

To very young birds caterpillars are especially attractive. Only 3 of the 79 nestlings estimated to be less than 6 days old had failed to eat these larvæ. In the stomachs of 10 of these, caterpillars formed over three-fourths of the food, while the average for the lot was nearly half. In the case of two nestlings, apparently more than 10 days old, caterpillars formed the entire stomach content.

A large part of the caterpillars eaten by the starling are cutworms, a fact which may be attributed to the bird's habit of searching for insect food on the ground. Cutworms are chiefly nocturnal in their habits, but their high percentage in the food of young starlings indicates either that they are secured by the parents from beneath the surface or, which is likely, that a part are picked up in the early morning hours before the insects have secreted themselves for the day.

Beetles of various kinds constitute the next largest item (29.98 per cent) in the food of nestlings, of which nearly half (14.58 per cent) are members of the family Scarabæidæ, in which is found that notorious pest, the white grub, better known to the city dweller in its adult form, the May beetle (*Phyllophaga*). During late May and early June adult May beetles are favorite items of food with young starlings. One brood of 4 nearly fledged young had been fed entirely on these insects, at least 32 individuals being eaten, and another brood of 4 had eaten 27, which constituted 82 per cent of their food. As would be expected, the larvæ of these beetles are seldom eaten unless the parent birds are securing food on newly plowed fields. A few other phytophagous scarabæids of the genera *Euphoria*, *Ligyris*, *Cotalpa*, *Anomala*, *Diplotaxis*, and *Serica* also were eaten, but in no case were the insects of economic importance or the quantity taken worthy of note. Nestling starlings eat by no means as

many coprophagous scarabæids as do their parents, who, in late summer and in fall, capture numbers of the common small genera on the wing. Of these, *Aphodius* appears to be the favorite for the nestlings.

Ground beetles (Carabidæ) formed a little more than 8 per cent of the young starlings' food, a proportion about equal to that taken by the adults in May and June. They were found in two-thirds of the stomachs examined, but in only one case was the quantity taken more than half the stomach contents. Conspicuous among the distinctly beneficial carabids eaten is the fiery caterpillar hunter (*Calosoma calidum*). This insect was identified in 17 stomachs. The large *Harpalus caliginosus* was present in 54 stomachs, *Chlenius tomentosus* in 46, and members of the genus *Anisodactylus* in 76. The presence of a considerable number of the last-named genus, together with specimens of *Amara*, show that not all the ground beetles eaten should be charged against the starling, as some of them are distinctly vegetarian.

The young starlings' consumption of weevils is nearly three times as great as that of the adults during the same period, and while in bulk the portion taken is small (3.26 per cent), it contains one item of considerable interest, the clover leaf weevil (*Hypera punctata*). (See Pl. III, fig. 1.) This insect constituted by far the largest portion of the weevil food. It was present in 53 stomachs, and the larvæ occurred in 34. One brood of 3 newly hatched young had been fed a total of 59 of these larvæ, which, together with 3 adult weevils of other genera, formed nearly 70 per cent of their food. The best record for the destruction of adult weevils was made by a brood of 4 half-grown nestlings that had consumed 30 individuals of two other clover pests (*Sitona hispidula* and *Phytonomus nigrirostris*) along with a number of billbugs (*Sphenophorus* sp.).

The remaining beetle food, comprising 4.11 per cent, was divided among a number of families. Leaf beetles (Chrysomelidæ) and rove beetles (Staphylinidæ) were best represented, but in no case was the quantity eaten of importance.

As the nestling period is too early in the season to permit a heavy consumption of grasshoppers, a large part of the orthopterous remains found (11.31 per cent) was composed of crickets. These were present in 134 stomachs, frequently associated with a grasshopper or two. One brood of 4 young starlings about ready to leave the nest had eaten 19 crickets and 4 grasshoppers, which totaled over 81 per cent of the food; another brood, just hatched, had been fed 13 crickets and 7 grasshoppers, which formed over two-thirds of their diet; and in the case of two other broods of 4 and 5, respectively, the orthopterous food constituted over two-thirds of the stomach contents. Most of the crickets eaten by nestlings are the common field cricket

(*Gryllus pennsylvanicus*), while many of the grasshoppers belong to the genus *Melanoplus*.

There is nothing of particular interest in the remaining insect food of young starlings. None of the other orders were represented by as much as 1 per cent. Among the Hymenoptera eaten, ants were prominent, and of the Hemiptera, soldier bugs (Pentatomidæ) formed the greater part.

Of animal items other than insects, spiders are most conspicuous. They were present in 182 of the 325 nestling stomachs examined and formed 8.56 per cent of the food, compared with 1.28 per cent of that of adults for the same period. Spiders are especially acceptable to nestlings of a day or two, as their thin-walled stomachs are unable to assimilate hard food. These creatures were found in the stomachs of 71 of 79 starlings less than 6 days old, and brood after brood was found in which every individual had been given one or more spiders. In some instances upward of a hundred were found when an egg sac filled with young spiders had been swallowed. A large part of the spiders eaten belong to the family Lycosidæ, the wolf spiders, which are terrestrial in habit and are generally considered less beneficial than those species which construct webs for the capture of flying insect pests.

The greatest difference between the food habits of old and young starlings is in the quantity of millipeds eaten. These form nearly a third (32.95 per cent) of the sustenance of the adult birds during May and June, but less than a twentieth (4.56 per cent) of the food of the young. In the frequency also of feeding on millipeds the nestling lags behind its parent. About 52 per cent of the nestling starlings were fed on millipeds, while fully 78 per cent of the adults had taken such food during the same time. It would seem, then, that the parent birds in their search for food for the young either deliberately pass up many a milliped or else devour them themselves as they proceed.

Nothing of importance appeared in the remaining miscellaneous animal matter, which formed less than 1 per cent of the food.

VEGETABLE FOOD.

Of the vegetable food consumed, cultivated cherries are the only item of importance. This fruit was eaten by 30 of the 325 nestlings collected and formed 3.18 per cent of the food, as compared with 8.01 per cent for adults during the same period. Most of the cherries eaten by the nestlings are brought to them the last few days they are in the nest, when they have acquired a dietary very similar to that of their parents. During this short time, however, a hungry brood of 5 or 6 can make away with considerable fruit. A nest box which had been occupied by only one brood near Closter, N. J., con-

tained 114 stones of cultivated cherries when cleaned on July 11. The economic significance of the starling's taste for cherries is fully discussed under the food of the adults, on pages 26 to 28.

The remaining vegetable food, less than 2 per cent, is composed largely of rubbish. Mere traces of corn, oats, and wheat were present in a few stomachs.

FOOD PREFERENCES AT DIFFERENT AGES.

In order to reveal the changes that take place in the food preferences of the nestling starling from the time it receives its first meal to the time it is ready to leave the nest and shift for itself, the nestlings' stomachs were arranged in three groups, representing as nearly as possible the first, second, and third periods of nestling life. These groups include, approximately, (1) birds from 1 to 5 days old; (2) those 6 to 10 days old; and (3) all above 10 days of age. Each group was well represented, there being 79, 94, and 122 stomachs, respectively. Fourteen additional nestling stomachs on hand could not be used, as definite data concerning their age was lacking. The information derived from the regrouping of this material is presented in condensed form in Table III and graphically represented in figure 3.

TABLE III.—*Monthly percentages of various kinds of food eaten by nestling starlings, showing the changing character at different ages (see fig. 3).*

Age of nestlings.	Ground beetles.	May beetles, etc.	Weevils.	Grasshoppers and crickets.	Caterpillars.	Millipeds.	Spiders.	Miscellaneous animal matter.	Cherries.	Miscellaneous vegetable matter.
1 to 5 days.....	2.43	3.91	5.59	13.96	45.26	1.48	23.44	2.98	0.18	0.77
6 to 10 days.....	11.59	18.33	4.49	11.23	34.88	5.34	3.57	5.93	3.36	1.28
10 or more days.....	7.69	18.25	1.02	8.98	37.81	6.38	3.28	7.61	4.76	4.22

It will be noticed that as the bird grows older there is a decrease in its consumption of soft and easily digested foods. The bulk of spiders eaten, for instance, is confined to the first few days of the bird's life. In the case of caterpillars the decrease is not uniform, although it is apparent that the very young birds are fed more than those a little older. There is also a gradual lessening in the quantity of crickets and grasshoppers taken. Under the heading "weevils" a similar decrease is recorded, but instead of the hard-shelled adults being so popular with young starlings, it is the larvæ of the clover leaf weevil which forms the bulk of the food. In the case of ground beetles and May beetles, as well as with millipeds, the younger nestlings are given smaller quantities. The same is true for the principal vegetable item, cultivated cherries. Only two of the 79 starlings less than 6 days old had been fed such fruit.

From the foregoing detailed account of the food of nestling starlings and the comparisons made with the food habits of the parent birds at the same time of year, it is apparent that the habits of the young materially raise the starling's economic status in the early summer months. In the consumption of destructive caterpillars, crickets and grasshoppers, and scarabæid beetles, three of the favorite food items of starlings, the young birds excel, and in the destruc-

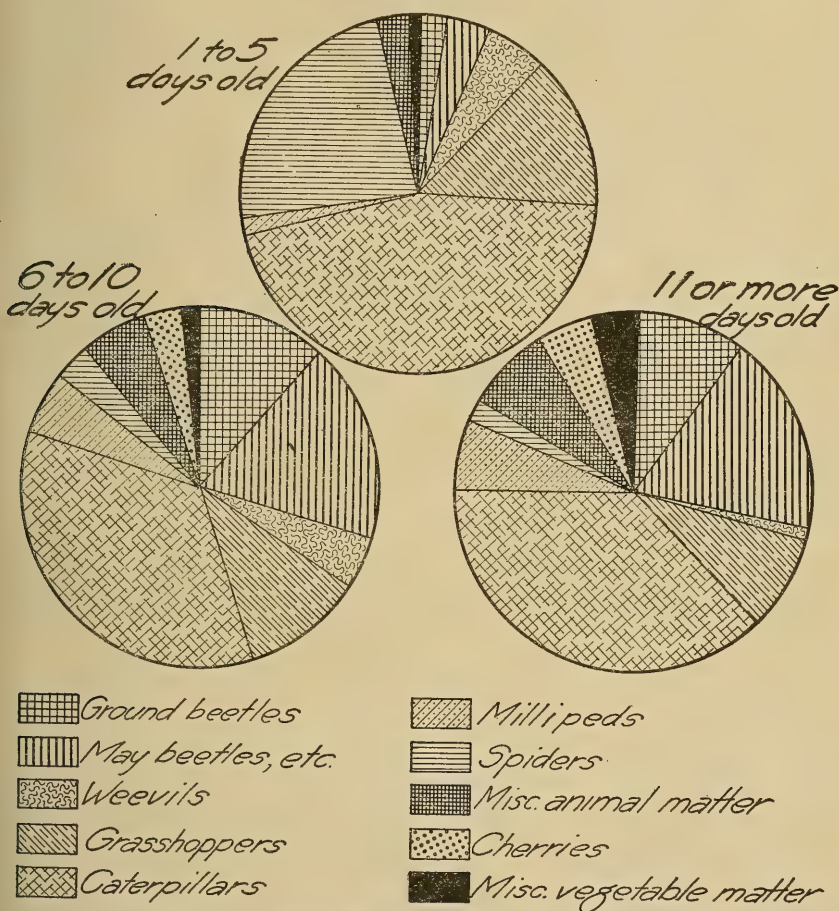


FIG. 3.—Chart of food of 295 nestling starlings, showing its changing character during the three stages of nestling life. In Table III, page 44, the same information is presented in percentages. Explanatory remarks on both chart and table are given on page 44.

tion of beneficial ground beetles and cultivated cherries they are not so culpable as their parents. Correlated with this demonstrated superiority in food habits are the facts that, bird for bird, nestlings consume more food than adults and that in the case of the starling they outnumber the adults two to one. Confronted with such an array of favorable testimony the worth of the young starling can be scarcely overestimated.

RELATION TO OTHER SPECIES OF BIRDS.

The antagonism between starlings and other birds constitutes one of the most frequently heard complaints against this species. This is especially true in thickly settled regions where the natural nesting sites of hole-nesting birds have been largely replaced with artificial ones in the form of bird boxes. This fact in itself has a tendency to bring to human attention most of such conflicts, as many of the bird boxes are in dooryards where they are under more or less constant observation. It must also be borne in mind that the driving out of native species which have been induced by enthusiastic bird lovers to take up sites in the dooryard, will be more keenly felt than the molesting of breeding birds at a greater distance from the house and with which there has been less intimate acquaintance.

While particular attention was given to this complaint during the breeding season, little antagonism was actually observed. However, as acts of vandalism last for just a moment or two, it is not surprising that more instances were not noted. It is apparent, then, from the nature of the case that data of this kind must be secured largely from the notes of reliable observers. Those who have had the fortune to witness such activities report that bluebirds and flickers suffer most, but martins, house wrens, robins, English sparrows, and a few other wild species, as well as domestic pigeons, are also bothered in their nesting operations.

Unrelenting perseverance dominates the starling's activities when engaged in a controversy over a nesting site. More of its battles are won by dogged persistence in annoying its victim than by bold aggression, and its irritating tactics are sometimes carried to such a point that it seems almost as if the bird were actuated more by a morbid pleasure of annoying its neighbors than by any necessity arising from a scarcity of nesting sites. Illustrative of this are the experiences of a pair of bluebirds observed at Norwalk, Conn., building a nest in a cavity high in an elm tree. On April 8 two starlings were seen sitting nearby, whistling and squealing. They were not noted attacking the bluebirds, but the next afternoon the bluebirds had disappeared and the starlings were carrying nest material into the cavity. The next day the bluebirds tried to get into a wren box having an opening too small for their passage. A day or two later four bird boxes were erected in the vicinity, and the bluebirds promptly began to build in one. This apparently aroused the displeasure of the starlings; so they entered the box and removed the nest material. The same performance was repeated at two of the other boxes, and it was not until the bluebirds had taken up the last box, which was provided with a 1½-inch opening, through which the starlings could not pass, that they were able to lay a set of eggs. That misfortune

still attended the bluebirds was disclosed one morning when the male was found dead beneath the nest and the eggs were deserted by the female. There was no evidence, however, to connect the starlings with the final disaster. Additional reliable evidence of bluebirds being driven out by starlings was secured at Norwalk, Wilton, and West Cornwall, Conn.; Groton, Mass.; Medford, Long Island, N. Y.; and Adelphia, N. J.

In contrast with such actions was the situation presented in an orchard at Norfolk, Conn., not far from the scene just described. Here a pair of bluebirds and two pairs of starlings conducted their family affairs peaceably in close proximity to each other. At Hartford, Conn., a pair of bluebirds and three pairs of starlings nested in natural cavities in apple trees located in two adjacent city lots. The owner of the property said he had watched the birds closely and did not see any evidence of antagonism between the species.

In contests with the flicker the starling frequently makes up in numbers what disadvantage it may have in size. Typical of such combats was the one observed on May 9, at Hartford, Conn., where a group of starlings and a flicker were in controversy over a newly excavated nest. The number of starlings varied, but as many as 6 were noted at one time. Attention was first attracted to the dispute by a number of starlings in close proximity to the hole and by the sounds of a tussle within. Presently a flicker came out dragging a starling after him. The starling continued the battle outside long enough to allow one of its comrades to slip into the nest. Of course the flicker had to repeat the entire performance. He did this for about half an hour, when he gave up, leaving the starlings in possession of the nest.

On June 19, at Port Chester, N. Y., a controversy was observed between a pair of starlings and a pair of flickers, whose brood was about to leave the nest, which was about 30 feet from the ground and within 25 feet of a house. When first observed one of the starlings was perched a few feet from the nest, in the entrance to which was one of the flickers. Whenever this flicker relaxed its vigilance for a moment one of the starlings would immediately make a dart for the nest opening. A scuffle would ensue in which both flicker and starling would come tumbling to the ground and a few feathers would fly. In the meantime the other flicker and starling would take up the waiting game in the tree top. This condition had prevailed for several days, and after a day or two more of continuous conflict the flicker succeeded in bringing forth its brood unharmed. The nest cavity was not then taken over by the starlings.

At Gwynedd Valley, Pa., an observer told of the killing of two broods of young flickers hatched in a tree in his dooryard. He had prevented the starlings from nesting in this cavity by repeated shoot-

ing early in spring, but was unable to prevent the destruction of the young flickers, which were killed by being dragged from the nest and dropped to the ground. At Closter, N. J., a similar conflict was reported in 1915, but in the following year the tables were reversed, for, in a dispute over a nest box only a few rods from the site of the flicker tragedy of the former year, a starling engaged in a struggle for a nest box met its death, apparently in a battle with a flicker. That less serious outcomes sometimes result from starling-flicker feuds was indicated by circumstantial evidence at a point near Hopewell Junction, N. Y. A brood of starlings was occupying a nest cavity recently excavated by flickers in accordance with the approved principles of flicker architecture, the entrance being on the lower side of the limb, protected from drainage. In a neighboring tree was found a brood of 6 half-grown flickers located in a natural cavity, similar to ones often chosen by starlings, a hollow limb with the entrance exposed upwards and with an opening full 5 inches in diameter. All circumstances seemed to indicate that the birds had simply exchanged nesting sites. Additional reliable evidence of the starling's aggressive tactics against flickers, some of which involved the killing of young as well as the usurping of nest sites, came in reports from Hartford, Norwalk (2), West Cornwall, and Portland, Conn.; Woodstown and Adelphia, N. J.; and Ambler and Maple Glen, Pa.

Purple martins suffer to only a limited extent from the starling's demand for nest sites. Throughout Connecticut and much of north-eastern New Jersey the martin is not an abundant bird, so while houses put up for martins in various localities were usually occupied by starlings and English sparrows, there was little chance of their having been tenanted with martins, even had they not been occupied by the foreigners. One martin house at Norwalk, Conn., was occupied by a pair of sparrow hawks on one side and three pairs of starlings on the other. At Hadlyme, Conn., a colony of fully 50 pairs of martins conducted unmolested their nesting operations under the close scrutiny of starlings that nested near by. An observer from Adelphia, N. J., reported that he had witnessed an attack on martins in his yard. He had erected two martin houses of four compartments each early in the year. One was occupied by starlings, and when a pair of martins appeared and attempted to take up the other abode a fight occurred. A starling was observed going into the martin house, and after pulling out one of the inmates dragged out the nest material. The martin was subsequently attacked whenever it approached and it finally left the premises. In this and in another case at Adelphia the martins had come to the boxes for the first time.

The two most specific reports received, bearing on the relation of starlings to wrens, are conflicting. In one, at Norwalk, Conn., a pair of starlings flew to a wren's nest, and pulled the bird out and

killed it; while in the other, at Ambler, Pa., 11 pairs of wrens nested in peace in a yard of about an acre, although starlings were common in the breeding season.

The single record of starlings attacking a red-headed woodpecker comes from Baltimore, Md., where a combat was observed over a nest cavity in a telephone pole.

That the aggressions of starlings are not entirely restricted to attacks on hole-nesting species is apparent from the fact that after bluebirds and flickers, robins seem to be the birds most frequently molested. Although no observation of this kind was made by the investigators, reliable evidence has come from outside sources. At Ambler, Pa., two nestling robins were killed by starlings, the victims being dispatched by powerful pecks on the head. At East Norwalk, Conn., a starling was seen to peck and break all the eggs in a robin's nest. At the bird sanctuary at Fairfield, Conn., the remains of a robin's nest destroyed by starlings was seen, the caretaker witnessing this act of vandalism; after the robins had rebuilt the structure it was again destroyed, presumably by starlings. Other corroborative evidence on this point was secured at Gwynedd and Spring House, Pa.; Adelphia, N. J.; Southampton, N. Y.; and Hadlyme, Conn. Single attacks on a Baltimore oriole's nest and the young of a chipping sparrow were reported.

It was an almost universal observation throughout Connecticut and New Jersey that the English sparrow is decreasing in numbers, and many persons attribute this to the starling. No belligerent acts between these two species, however, were witnessed in the field, though several instances of the usurping of the nesting or roosting places of English sparrows by starlings have been reported. In a number of cases these two species were observed breeding in close proximity, and under one water tank their nests almost touched.

A few instances of starlings attacking domestic pigeons were reported. At Middletown, R. I., it was found necessary to wage constant warfare on the starlings to keep them from nesting in one pigeon loft, where they appropriated for their own domestic affairs the boxes put up for the pigeons. They carried in so much material that they filled the boxes and on one or two occasions dragged it in so rapidly as actually to barricade the setting pigeons, which were entirely unresisting. At Closter, N. J., it was reported that starlings had entered a pigeon loft, driven out the adults, and then, dragging out the squabs, had let them fall to the ground, where they were killed. Opposing testimony was presented from experiences on a squab farm at Stanton, N. J. Here the starlings nested peaceably along with the pigeons and the only trouble that the latter had occurred during cold weather, when starlings in considerable numbers used the coops

for roosting places. Whenever a lantern was brought into the building at night the starlings flew about in great commotion and, frightening the pigeons, caused some of the setting birds to leave their eggs. Starlings were reported on occasions to have driven pigeons even from church towers. At Norwalk, Conn., and Newburgh, N. Y., however, towers were found where pigeons were successfully raising young in the immediate presence of roosting starlings.

To determine whether a mere scarcity of nesting sites is the cause of the antagonism between starlings and other species, 24 nest boxes were erected, 12 in the vicinity of Closter, N. J., and 12 about Norwalk, Conn. These boxes were of a size commonly provided for flickers, measuring approximately $4\frac{3}{4}$ by $5\frac{3}{4}$ by 16 inches (interior dimensions) and fitted with a $2\frac{1}{2}$ -inch hole, and so constructed that the nests could be readily inspected by means of a removable front. In some of these boxes the size of the hole was reduced by tacking on the front small boards containing circular openings, some $1\frac{3}{4}$ inches and some $1\frac{5}{8}$ inches in diameter. These were used to determine the smallest opening through which a starling can pass. The boxes were occupied readily both by starlings and bluebirds; in most cases this was not due to a lack of natural nesting sites, as there were many to be had. In one orchard a pair of starlings showed such a marked preference for a natural cavity that they raised two broods therein, although 3 boxes were in the immediate vicinity, unoccupied at the time their nest was started. Following is a summary of what transpired at the 24 boxes:

Four boxes failed to have any bird activity connected with them; 18 had starling nests started; 14 had starling nests completed; 10 had starling eggs hatched (in 3 other instances the eggs were removed); 8 had bluebird nests started, four of which produced young; and 1 had a completed nest of house wrens.

None of the 6 boxes with $1\frac{5}{8}$ -inch opening was occupied by starlings; 5 of 7 boxes with $1\frac{3}{4}$ -inch opening were occupied by starlings; 10 of 13 boxes with $2\frac{1}{2}$ -inch opening were similarly occupied; and at 3 boxes bluebirds were driven away by starlings.

In summarizing the evidence bearing on the relation between the starling and our native birds during the breeding season, it is apparent that the bluebird and flicker suffer most. Both have no doubt to a certain extent been driven away from the vicinity of the dooryard. Regarding the seriousness of these attacks and the ultimate consequences to the population of the species it is believed the fears of many bird lovers are exaggerated. While instances such as those cited are numerous and often have resulted fatally to the birds attacked it must be borne in mind that this information is the compilation of more than six months' constant investigation, during which time

no opportunity to secure data on this point was overlooked. Bluebirds are common and generally distributed in the sections thickly settled with starlings, and although observers have noted their disappearance in small areas confined to a dooryard or two, it is the opinion of those who are qualified to judge the general abundance of these birds that in Connecticut and northeastern New Jersey bluebirds have either held their own or increased in numbers in the last few years. Since bluebirds will continue to nest commonly in localities away from human habitation where they have little to fear from starlings, and since even in the dooryard, their nests, eggs, and young may be protected by providing nest boxes having an opening no greater than $1\frac{1}{2}$ inches in diameter, there is little danger of the race as a whole being placed in jeopardy.

The flicker also will be driven from the vicinity of houses, but it, too, will always find a refuge in wilder situations to which the starling seldom goes. In those parts of Connecticut, New York, and New Jersey where the starling has been a common bird and in competition with the flicker for at least 15 years the latter still maintains as conspicuous a place in the bird world as it does in other parts of these States where the starling is not yet common. The same can be said of the robin, which in northeastern New Jersey and along the Connecticut shore is an extremely abundant bird. Martins are more abundant in western, central, and southern New Jersey than in the center of starling population, but such a condition of relative abundance existed before the advent of the starling, and it can not be construed as a result of starling aggression. Neither can the apparent decrease in the English sparrow population throughout New Jersey and parts of New England in the last 10 years be correlated with the spread of the starling, as in many sections where the decrease of the sparrow has been noted the starling has not yet arrived in numbers. As for the other species at present known to be attacked by starlings, the acts of vandalism are so occasional that the effect is negligible and the situation is by no means as serious as that presented by the predatory habits of the blue jay, the grackle, or the crow.

A consideration of the economic significance of displacing certain native species by the starling involves judgment of the relative worth of the various species. A comparison of the merits of the starling with those of its breeding competitors reveals that it is certainly more valuable than the robin, flicker, or English sparrow; that it has food habits fully as favorable as those of the house wren; and that the bluebird and martin are the only species with which the starling is in intimate competition whose economic worth might be considered greater than that of the starling.

Field observation sheds some light on the added competition for food imposed upon native species by the presence of the starling. During the breeding season, robins in suburban sections and meadowlarks in the more open country are the species thrown most intimately in contact with the newcomer. The robin finds its customary supply of cutworms in the garden reduced by the diligent search of the starling; earthworms, a favorite food of the robin in wet weather, also are taken by the starling, but the supply of these appears to be ample for both. In the case of the meadowlark, such items as cutworms, clover leaf weevils, and other beetles constitute the food supply most frequently sought by both species.

After the breeding season the starling comes in competition with several additional species in its search for food. In feeding on meadow and pasture land, its closest associate is the cowbird, and a mixed flock of these two species is a common sight about dairy herds. Contrary to expectation, however, the food habits of the two do not seriously conflict at that time of year. A comparison of the stomach contents of cowbirds and starlings secured from the same flocks showed that while starlings were feeding most heavily on grasshoppers and crickets, cowbirds were satisfying themselves largely by picking up seeds of ragweed and foxtail grass. Similar conditions existed in mixed flocks of starlings, red-winged blackbirds, and grackles roaming through cornfields. Ripening corn formed the major portion of the food of the red-wings and grackles, while starlings ate comparatively little. Probably the greatest influence exerted by the starling on the food supply of other birds is occasioned by its consumption of wild fruit during late summer and early fall. Wild cherry and sour gum trees heavily laden with fruit are soon stripped when a flock of several hundred starlings feeds continually in the vicinity, and, although the total supply of this food is enormous, instances were observed where locally such birds as robins, catbirds, and cedar waxwings were compelled to seek other sources of food. During winter starlings secure a certain portion of the food formerly eaten by English sparrows, especially about dumping grounds of cities. Where bird lovers have taken pains to attract native species they have often found the foreigner greedily consuming all the food they could supply, with the result that the cost of attracting birds rose almost to a prohibitive point.

Here again must judgment be given on the relative worth of the species concerned before the seriousness of the starling's consumption of the former food supply of other birds can be understood. After carefully weighing all the evidence available, it is safe to state that in the area covered by this investigation the starling is economically the superior of the robin, the catbird, the red-wing, the grackle, the

cowbird, or the English sparrow, and that in this competition for food the meadowlark is the only species whose added difficulty in sustaining itself is to be deplored.

NATURAL ENEMIES.

Very little evidence is at hand regarding the natural enemies of the starling. At Norwalk, Conn., a cat was seen carrying a freshly caught fledgling; and it is probable that a number are thus captured, as cats are numerous in the whole region. Far more robins, catbirds, and other birds are destroyed in this manner, however, for starlings are better protected in the nest and are also able to fly better when they leave the nest than are many of our common native birds.

Hawks were several times noted flying with or about flocks of starlings without attempting to capture any of them. At Bay Shore, N. Y., a curious performance was noted on three successive afternoons. A pair of sparrow hawks used the dead tops of several large locust trees as a lookout point for their hunting. Late in the afternoons the starlings appeared in this locality on their way to roost. As they passed, the sparrow hawks darted out, apparently in pursuit, but they never struck a bird. Instead, both the starling flock and sparrow hawks went through a series of intricate evolutions, apparently alternating in the rôle of pursuer and pursued. Occasionally the performance would be varied by a starling swooping down on a hawk as it perched on a limb, driving it off: then followed the same evolutions as when the hawk was the aggressor.

At Freehold, N. J., a sharp-shinned hawk was seen diving into a tree full of young starlings, but the latter, rushing to the center of the thick foliage, escaped harm. At Glen Cove, N. Y., a Cooper hawk was observed to dart from a tree into a passing flock of starlings and, striking one, to carry it away. A young starling was found also in a nest of a Cooper hawk at Wilton, Conn. These instances are enough to show that the birds of prey have learned to take their toll from the newcomer, but give little basis for any estimate as to their effect in checking its increase and spread.

Many of the starlings collected were heavily infested with intestinal parasites, but no evidence was secured as to the effect these might have on the mortality of the birds.

Cold weather seems to have some effect in checking the increase of starlings as in the vicinity of winter roosts it is common to find dead birds. This is particularly true in northern New Jersey, the region of their greatest abundance.

ERADICATION OF ROOSTS.

Soon after the first brood of starlings begins to leave the nest, sometimes as early as the middle of June, one may find these birds resorting to nightly roosts (see pp. 11-13). These may be in trees or in church towers, barn cupolas, sheds, etc.; but up to the advent of cold weather the greatest number of starlings gather in tree roosts. Frequently these are established in the residential sections of cities, where the noise in the evening and early morning, with the attendant filth and odor from their droppings, makes the starlings most unwelcome birds. But by no means all of the nuisance should be attributed to starlings, as in most roosts of any size grackles, robins, English sparrows, cowbirds, red-winged blackbirds, and even purple martins help to swell the numbers. Plainfield, Newark, Orange, Montclair, and Glen Ridge, N. J.; Greenwich, Fairfield, and Hartford, Conn.; Glen Cove, N. Y.; and Germantown and Ambler, Pa., are a few of the places where roosts, in which starlings formed a large part of the assemblage, have proved to be a distinct nuisance.

The roost encountered at Orange, N. J., is a typical one. Here, as in many other instances, the birds had selected tall elms and maples overhanging roadways and dooryards. When visited on July 15, 1916, the ground beneath the larger trees was whitened with excrement. Feathers from the molting birds and the bodies of those that had died littered the ground, and the offensive odor arising, especially in humid weather, permeated the whole neighborhood.

This roost was occupied by starlings, grackles, and a few hundred robins. Observations made on the incoming birds indicated that the ratio between the number of starlings and grackles was about 3 to 2. During the early evening starlings greatly predominated, but as darkness deepened the proportion of grackles increased, while the last to enter the roost were robins. On July 17, during four minutes at the height of the influx (6.56 to 7 p. m.) 900 birds entered the roost from the south, and on the following night, during a period of 38 minutes, 3,100 were noted coming from the same direction. From these and other observations it was estimated that the roost was occupied by from 6,000 to 8,000 birds. During the entire process of assembling, the birds that were already gathered kept up an incessant din—the starlings with their variety of whistles and rasping notes and the grackles with their monotonous “checks” and unmusical squeaking calls. The clamor gradually lessened as darkness came, but a few of the birds might be heard at odd times all through the night. At the peep of day the gathered thousands would break out with a volume of song that terminated abruptly the slumbers of all light sleepers in the vicinity. This accomplished, the birds would depart rather suddenly on their daily search for food.

In previous years residents of the vicinity had undertaken measures, more or less feeble, to remove the objectionable birds. Some of these afforded temporary relief. Roman candles shot on one or two nights drove the birds away for a short time. Three incandescent lamps placed in a tree in the center of the roost gave relief to that immediate vicinity. The ringing of a bell placed in another tree served to drive away the birds in the early morning hours and shorten their annoying daybreak serenade, and a little desultory shooting also had been done, but with no lasting results.

Operations with a view of testing some of these methods of roost eradication were begun on July 17, at the Orange roost. A shotgun was used in the early evening, and when darkness arrived a number of Roman candles were discharged. Five successive nights of attack removed the roost. During these operations two observations of importance in connection with roost eradication were made. One was that the firing of a gun early in the evening, just as the birds are coming to roost, makes a more effective impression than one fired after the colony has settled for the night. When there is still daylight the frightened birds will fly for some distance before alighting, while later in the evening the birds move only a few yards from their former perch. It was also noted that in a mixed roost adult starlings were the first to take flight and young starlings were next to leave; grackles were less easily driven away, while robins were practically fearless, few of them leaving the roost even after five nights of attack. The relief obtained, however, was but temporary. In about 10 days the birds, not being further molested, reoccupied the roost. On August 24, a second attempt was made to drive them out, and after 6 nights' shooting they left, not to return that season.

On the last 6 nights of September a starling-grackle-robin roost at Freehold, N. J., was attacked with the shotgun only and completely removed. The birds apparently chose a new roosting place at some distance from Freehold, for when the roost had been eradicated, comparatively few starlings could be found in the daytime anywhere in the country surrounding the town, where previously they had been common.

A single night's shooting at a roost composed entirely of starlings at Fairfield, Conn., during which 40 of the birds were killed, gave the desired results.

A roost at Montclair, N. J., had been a source of considerable trouble for several years and measures had been taken to eradicate it. Roman candles had no effect, but four men using shotguns loaded with blank cartridges for three consecutive nights succeeded in driving the birds away. However, they moved to a point in Glen Ridge, N. J., where they became equally troublesome.

Experiments were made by the municipal authorities of Montclair in 1916 to determine the usefulness of a sticky substance applied to the branches of the trees of the roost. This had no apparent effect in deterring the birds, although six or seven trees near the center of the roost had their branches well smeared with it. The sticky, resinous gum used was applied with small paddles, the climbers using a boatswain's chair to reach the upper and outer branches. As in several other cases the shotgun had to be used to bring relief.

At Hartford, Conn., several years ago, a roost of about 5,000 starlings and grackles was established on one of the principal residential streets, where it became such a nuisance that the city authorities took measures to remove it. Objection to the use of a shotgun was made by local bird lovers, who volunteered to drive the birds away by firing Roman candles. Three nights' work, in which from 3 to 15 men armed with Roman candles participated, removed the roost.

From present experiences it is apparent that neither the shotgun nor the Roman candle, however, effects a lasting cure. Each one, when used persistently, has served to remove roosts, but in either case vigilance must be used to prevent the birds from reestablishing themselves. In a few instances, as at Hartford, Roman candles did the work effectively, but at other roosts such measures have failed. A shotgun loaded with black powder shells, fired on 5 or 6 consecutive evenings, will give more certain results. Such treatment can be recommended for eradicating tree roosts of starlings and grackles wherever State and local laws permit.

Starling roosts located in church towers, where they have sometimes become a nuisance on account of the attending filth, can be abolished by the use of wire screen of a mesh of $1\frac{1}{4}$ inches or less. This method is almost universally resorted to in places thickly populated with starlings.

CONTROL MEASURES.

Outside of the work done on roosts and the activities of caretakers of a few bird preserves, few efforts toward reducing the numbers of starlings have been made, but mention of some of these may be useful to those desiring to control the birds where they are injurious either to crops or buildings.

One fact connected with the behavior of starlings brought out repeatedly in field work is that the birds are easily frightened by gunfire and soon become exceedingly wary. A few gunshots are usually sufficient to drive them away from the vicinity of crops upon which they are feeding. This is especially true when they are eating cherries.

Where starlings become objectionable about dooryards by reason of the filth connected with their breeding operations, their activities

may be curtailed by closing all cavities which might be used for nests, or reducing the diameter of the entrances to $1\frac{1}{4}$ inches or less.

While wholesale destruction of these birds, where extermination of the species in this country is the object sought, can not be recommended, occasion may arise where local overabundance will accentuate some of the injurious habits of the species, and make a reasonable reduction in their numbers justifiable. Raids on their fall and winter roosts appear to be effective means of accomplishing this. In church towers, especially, large numbers may be easily captured at night. No poisoning method appears practicable in winter, but trapping has met with moderate success on bird preserves. An ordinary screen ash-shifter propped up on one side with a stick was used to advantage in one case, and after baiting the area below it, the trap was sprung by pulling a string attached to the supporting stick.

LEGISLATION.

The popular attitude toward the starling has been reflected in State game laws. In all States where the bird is present even in moderate numbers it has been placed in the list of exceptions to protection. These States are Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, and Maryland. In Maine, where, in the extreme southwestern corner, a few starlings have appeared, these birds have been given protection, subject, however, to a provision in the State game laws whereby any birds or mammals (save beavers) may be killed when destroying crops.

SUMMARY OF EVIDENCE.

FOOD HABITS.

The food habits of a bird are of paramount importance in determining its desirability, and in the case of the starling knowledge on this subject is available from evidence revealed from a larger series of stomachs apparently than any heretofore used in the investigation of the food habits of a single species, supported by extensive field observation in areas in this country where the species is most abundant. Following are the more important findings:

As an effective destroyer of terrestrial insects, including such pests as cutworms, grasshoppers, and weevils, the starling has few equals among the bird population of the northeastern United States.

The most serious objection to the starling on economic grounds arises from its destruction of cherries. When its work is combined with that of the robin, which is fully as destructive and much less easily frightened, the chances for a successful crop of cherries, especially of early varieties, are poor.

The starling's work on apples is confined largely to isolated trees and to small, old orchards. Late varieties suffer more than those which mature at a time when there is still a great abundance of wild black cherries available. In the aggregate the apple damage is not great and is practically absent in young, well kept, productive orchards. Injury to peaches and pears is negligible, and the damage to grapes is at present confined to small arbors—the large vineyards suffering very little.

Contrary to the opinion of many farmers, especially in New Jersey, the starling secures an extremely small portion of its sustenance from either sweet or field corn. Its association with the actual depredators of cornfields, the red-winged blackbirds and grackles, accounts for its reputation. It is true that the starling, especially in the vicinity of roosts, does inflict some damage on corn, but compared with that done by the other species named this is very little. Its damage to small grain is negligible.

In the small city or suburban garden the starling's fondness for green stuff in spring and early summer has been the cause of some complaint, but in large truck-crop sections, where the bulk of such produce is raised, the aggregate loss is trivial.

An idea of the economic significance of the starling's food habits is gained by comparison with the food habits of certain well-known native birds, with some of which it frequently associates. A thorough consideration of the evidence at hand indicates that, based on food habits, the adult starling is the economic superior of the robin, catbird, flicker, red-winged blackbird, or grackle. It is primarily a feeder on insects and wild fruit—less than 6 per cent of its yearly food being secured from cultivated crops. What damage it does inflict is due not so much to the character of its food habits as to the fact that the flocking habit has allowed some minor trait to be emphasized to a point where local damage results. The decidedly beneficial character of the food habits of one, two, or sometimes three broods of nestlings, numbering 4 to 6 to the nest, adds materially to the favorable economic status of the species.

RELATION TO OTHER SPECIES.

While the advent of the starling doubtless has had some effect on native species nesting in the dooryard, it is not believed this bird will jeopardize any species as a whole. Economically considered, the starling is the superior of either the flicker, the robin, or the English sparrow, three of the species with which it comes in contact in its breeding operations. The eggs and young of bluebirds and wrens may be protected by the use of nest boxes with circular openings $1\frac{1}{2}$ inches or less in diameter. This leaves the purple martin the only species readily subject to attack by the starling,

whose economic worth may be considered greater than that of the latter, but in no case was the disturbance of a well-established colony of martins noted. In its search for food the starling also comes in competition with neighboring species, most of which, however, are the starling's economic inferiors. The meadowlark appears to be the only species which might be affected by this competition for food whose added difficulty in sustaining itself is to be deplored.

ROOSTS.

The objectionable habit possessed by the starling in common with several other species, particularly grackles and robins, of congregating in enormous roosts, usually in the residential section of a city, is, next to the damage resulting from the bird's food habits, the source of the greatest economic loss. The persistent use of firearms or Roman candles will remove these nuisances, but vigilance must be employed to prevent the reestablishing of the roosts in other places where they would be equally objectionable.

CONCLUSION.

It has been the purpose of this investigation to determine what should be our attitude toward the starling, in order that a correct judgment might be reflected by legislation governing the protection of the bird. Most of the starling's food habits have been demonstrated to be either beneficial to man or of a neutral character. Furthermore, it has been found that the time the bird spends in destroying crops or in molesting other birds is extremely short compared with the endless hours it spends searching for insects or feeding on wild fruits. Nevertheless, no policy would be sound which would give the bird absolute protection and afford no relief to the farmer whose crops are threatened by a local overabundance of the species. Consequently, the enactment of laws that afford protection to the starling, except when it is actually doing or threatening to inflict damage, appears to be the wisest procedure. With its ready ability to adapt itself to new environments, the starling possesses almost unlimited capacity for good, but it is potentially harmful in that its gregarious habits may abnormally emphasize some minor food habit which would be indulged in at the expense of growing crops. The individual farmer will be well rewarded by allowing a reasonable number of starlings to conduct their nesting operations on the farm. Later in the season a little vigilance will prevent these easily frightened birds from exacting an unfair toll for services rendered.

TABLE IV.—*List of items identified in the food contained in 2,626 starling stomachs examined, and the number of stomachs in which each was found.*¹

ANIMAL MATTER.

COLEOPTERA (GENUINA) (BEETLES).		COLEOPTERA—Continued.	
Unidentified adults.....	106	Carabidæ—Continued.	
Unidentified larvæ.....	137	Crataeanthus dubius.....	11
Cicindelidæ (tiger beetles):		Agonoderus pallipes.....	3
Cicindela purpurea.....	1	Agonoderus testaceus.....	1
Cicindela repanda.....	1	Agonoderus sp.....	5
Cicindela punctulata.....	9	Harpalus dichrous.....	1
Cicindela sp.....	20	Harpalus erraticus.....	1
Cicindela sp., larvæ.....	1	Harpalus caliginosus.....	144
Carabidæ (ground beetles):		Harpalus faunus.....	9
Unidentified.....	729	Harpalus pennsylvanicus.....	82
Unidentified larvæ.....	3	Harpalus compar.....	18
Omophron americanum.....	1	Harpalus erythropus.....	6
Carabus sylvosus.....	1	Harpalus herbivagus.....	2
Carabus serratus.....	4	Harpalus sp.....	318
Carabus vinetus.....	12	Selenophorus pedicularius.....	1
Carabus nemoralis.....	2	Stenolophus conjunctus.....	5
Carabus sp.....	11	Stenolophus sp.....	2
Calosoma sayi.....	1	Anisodactylus rusticus.....	89
Calosoma calidum.....	19	Anisodactylus carbonarius.....	1
Calosoma sp.....	8	Anisodactylus baltimorensis.....	3
Elaphrus fuliginosus.....	1	Anisodactylus lugubris.....	1
Elaphrus sp.....	1	Anisodactylus sp.....	224
Scarites subterraneus.....	22	Dytiscidæ (predacious diving beetles):	
Scarites sp.....	2	Agabus disintegratus.....	1
Bembidium versicolor.....	2	Hydrophilidæ (water scavenger beetles):	
Bembidium quadrimaculatum.....	1	Tropisternus glaber.....	2
Bembidium sp.....	3	Tropisternus sp.....	1
Patrobus longicornis.....	2	Philhydrus sp.....	1
Pterostichus sayi.....	4	Sphaeridium scarabæoides.....	21
Pterostichus lucublandus.....	121	Cereyon unipunctatum.....	1
Pterostichus patruelis.....	2	Cereyon sp.....	1
Pterostichus sp.....	83	Cryptopleurum minutum.....	1
Evarthrus sigillatus.....	3	Silphidæ (carrion beetles):	
Evarthrus sp.....	2	Unidentified.....	1
Amara avida.....	3	Necrophorus sp.....	3
Amara pennsylvanica.....	21	Silpha surinamensis.....	1
Amara impuncticollis.....	1	Silpha noveboracensis.....	3
Amara basillaris.....	3	Silpha americana.....	1
Amara fallax.....	1	Silpha sp.....	4
Amara musculus.....	2	Staphylinidæ (rove beetles):	
Amara sp.....	131	Unidentified.....	155
Dicælus elongatus.....	1	Quedius molochinus.....	1
Dicælus sp.....	20	Staphylinus maculosus.....	29
Platynus cupripennis.....	46	Staphylinus mysticus.....	9
Platynus nutans.....	1	Staphylinus sp.....	58
Platynus placidus.....	1	Philonthus politus.....	1
Platynus crenistriatus.....	9	Philonthus hepaticus.....	1
Platynus sp.....	15	Philonthus fusiformis.....	1
Casnonia pennsylvanica.....	38	Philonthus micans.....	1
Casnonia sp.....	32	Philonthus sp.....	14
Galerita janus.....	1	Stenus sp.....	3
Galerita sp.....	4	Cryptobium sp.....	2
Lebia grandis.....	1	Hesperobium sp.....	1
Lebia sp.....	1	Pæderus littorarius.....	2
Cymindis pilosa.....	8	Scaphidiidæ (shining fungus beetles):	
Cymindis sp.....	9	Bæocera sp.....	1
Chlaenius tricolor.....	2	Coccinellidæ (ladybugs):	
Chlaenius tomentosus.....	72	Unidentified adults.....	18
Chlaenius sp.....	133	Unidentified larvæ.....	1
Anomoglossus emarginatus.....	1	Megilla maculata.....	5

¹ A total of at least 494 specifically different food items have been found in the food of the starling.

TABLE IV.—List of items identified in the food contained in 2,626 starling stomachs examined, and the number of stomachs in which each was found—Continued.

ANIMAL MATTER—Continued.

COLEOPTERA—Continued.		COLEOPTERA—Continued.	
Coccinellidæ—Continued.		Lampyridæ (fireflies):	
Hippodamia convergens.....	4	Unidentified adults.....	11
Hippodamia 13-punctata.....	1	Unidentified larvæ.....	6
Hippodamia parenthesis.....	15	Chauliognathus pennsylvanicus.....	13
Hippodamia sp.....	3	Chauliognathus marginatus.....	12
Coccinella 9-notata.....	1	Chauliognathus sp.....	2
Coccinella sp.....	1	Telephorus carolinus.....	4
Adalia bipunctata.....	2	Telephorus bilineatus.....	4
Symnus americanus.....	1	Telephorus sp.....	5
Erotylidæ (banded fungus beetles):		Polemius sp.....	1
Languria mozardi.....	2	Cleridæ (checkered beetles):	
Cucujidæ (flat bark beetles):		Chariessa pilosa.....	1
Silvanus surinamensis.....	3	Scarabæidæ (lamellicorn beetles):	
Histeridæ (shining carrion beetles):		Unidentified adults.....	104
Unidentified.....	28	Unidentified larvæ.....	34
Hister biplagiatus.....	1	Canthon lævis.....	2
Hister harrisii.....	1	Canthon sp.....	2
Hister interruptus var. immunis.....	4	Copris minutus.....	1
Hister abbreviatus.....	1	Copris tilius.....	6
Hister americanus.....	5	Copris sp.....	1
Hister perplexus.....	1	Onthophagus nuchicornis.....	9
Hister subrotundus.....	1	Onthophagus hecate.....	9
Hister sp.....	17	Onthophagus pennsylvanicus.....	6
Nitidulidæ (sap-feeding beetles):		Onthophagus sp.....	6
Ips quadriguttatus.....	5	Atenius cognatus.....	19
Trogositidæ (grain and bark-gnawing beetles):		Atenius sp.....	8
Tenebrioides corticalis.....	1	Aphodius fossor.....	9
Tenebrioides sp.....	2	Aphodius fimetarius.....	106
Byrrhidæ (pill beetles):		Aphodius granarius.....	9
Unidentified.....	60	Aphodius inquinatus.....	16
Cytilus sericeus.....	1	Aphodius stercorosus.....	1
Cytilus sp.....	4	Aphodius sp.....	25
Byrrhus sp.....	4	Boibocerosoma farctum.....	2
Heteroceridæ (mud beetles):		Odontaeus cornigerus.....	1
Heterocerus sp.....	1	Geotrupes splendidus.....	2
Elateridæ (click beetles):		Geotrupes sp.....	1
Unidentified adults.....	303	Dichelonycha elongata.....	1
Unidentified larvæ.....	29	Serica vespertina.....	2
Adelocera discoidea.....	1	Serica sp.....	1
Cryptohypnus abbreviatus.....	2	Diploptaxis atlantis.....	9
Monocrepidius lividus.....	2	Diploptaxis sp.....	13
Monocrepidius vespertinus.....	9	Phyllophaga ephillida.....	1
Monocrepidius auritus.....	3	Phyllophaga fusca.....	30
Monocrepidius bellus.....	13	Phyllophaga anxia.....	10
Monocrepidius sp.....	11	Phyllophaga gibbosa.....	13
Drasterius elegans.....	17	Phyllophaga micans.....	4
Drasterius sp.....	12	Phyllophaga fervida.....	3
Agriotes mancus.....	4	Phyllophaga fraterna.....	6
Agriotes pubescens.....	1	Phyllophaga hirticula.....	55
Agriotes sp.....	1	Phyllophaga forsteri.....	10
Melanotus sp.....	5	Phyllophaga crenulata.....	3
Limonius griseus.....	10	Phyllophaga tristis.....	41
Limonius interstitialis.....	1	Phyllophaga sp.....	162
Limonius plebejus.....	2	Anomala lucicola.....	7
Limonius sp.....	7	Anomala sp.....	31
Corymbites pyrrhos.....	1	Cotalpa lanigera.....	6
Asaphes memnonius.....	1	Dyscinetus trachypygus.....	1
Buprestidæ (metallic wood-borers):		Ligyris gibbosus.....	10
Unidentified.....	2	Ligyris sp.....	2
Dicerca obscura.....	1	Euphoria fulgida.....	1
Dicerca lurida.....	1	Euphoria inda.....	12
		Euphoria sp.....	8

TABLE IV.—List of items identified in the food contained in 2,626 starling stomachs examined, and the number of stomachs in which each was found—Continued.

ANIMAL MATTER—Continued.

COLEOPTERA—Continued.

Cerambycidae (long-horned beetles):

Unidentified.....	9
Phymatodes variabilis.....	1
Monohammus scutellatus.....	1
Lepturges querci.....	1
Tetraopes canteriator.....	1
Tetraopes sp.....	1

Chrysomelidae (leaf beetles):

Unidentified.....	311
Donacia sp.....	1
Lema trilineata.....	2
Crioceris asparagi.....	1
Chlamys plicata.....	6
Chlamys sp.....	1
Bassareus sp.....	1
Cryptcephalus venustus.....	8
Cryptcephalus calidus.....	2
Cryptcephalus sp.....	6
Pachybrachys m-nigrum.....	1
Pachybrachys sp.....	3
Diachus auratus.....	1
Typophorus canellus.....	3
Typophorus quadrinotatus.....	8
Typophorus aterrimus.....	2
Typophorus gilvipes.....	1
Typophorus sp.....	27
Graphops pubescens.....	3
Graphops marcescens.....	3
Graphops sp.....	4
Colaspis brunnea.....	52
Colaspis sp.....	31
Nodonota tristis.....	1
Nodonota puncticollis.....	7
Nodonota clypealis.....	1
Nodonota sp.....	12
Labidomera clivicollis.....	1
Leptinotarsa 10-lineata.....	39
Zygogramma suturalis.....	17
Zygogramma sp.....	3
Calligrapha similis.....	10
Calligrapha elegans.....	7
Calligrapha lunata.....	2
Calligrapha sp.....	7
Plagioderia viridis.....	2
Gastroidea polygoni.....	2
Gastroidea sp.....	1
Phyllobrotica sp.....	1
Diabrotica 12-punctata.....	3
Diabrotica vittata.....	1
Diabrotica sp.....	2
Trirhabda canadensis.....	2
Trirhabda sp.....	1
Galerucella americana.....	10
Galerucella sp.....	63
Monoxia puncticollis.....	2
Oedionychis vians.....	2
Oedionychis thoracica.....	2
Oedionychis fimbriata.....	5
Disonycha crenicollis.....	1
Disonycha caroliniana.....	1
Disonycha triangularis.....	1
Disonycha xanthomelaena.....	2

COLEOPTERA—Continued.

Chrysomelidae—Continued.

Disonycha sp.....	2
Haltica ignita.....	5
Haltica rufa.....	1
Haltica sp.....	1
Systema hudsonias.....	7
Systema sp.....	3
Phyllotreta vittata.....	1
Phyllotreta armoraciae.....	1
Chaetocnema denticulata.....	13
Chaetocnema minuta.....	1
Chaetocnema sp.....	20
Dibolia borealis.....	1
Microrhopala vittata.....	35
Microrhopala xerene.....	2
Microrhopala sp.....	43
Coptocycla bicolor.....	1
Coptocycla plicata.....	1
Coptocycla sp.....	4
Chelymorpha argus.....	16

Tenebrionidae (darkling beetles):

Unidentified.....	10
Tenebrio obscurus.....	1
Opatrinus notus.....	106
Blapstinus moestus.....	1
Blapstinus metallicus.....	1
Blapstinus sp.....	31
Helops aereus.....	1

Anthicidae (antlike flower beetles):

Unidentified.....	1
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Meloidae (blister beetles):

Unidentified.....	2
Meloe americanus.....	1
Epicauta pennsylvanica.....	1

RHYNCHOPHORA (Weevils):

Anthribidae (fungus weevils):

Euparius marmoratus.....	1
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Curculionidae (curculios, or weevils):

Unidentified.....	267
Epicaerus imbricatus.....	2
Phyxeles rigidus.....	93
Otiorynchus sulcatus.....	8
Otiorynchus ovatus.....	61
Otiorynchus sp.....	2
Tanymecus confertus.....	5
Barypithes pellucidus.....	1
Sitona hispidula.....	510
Sitona flavescens.....	34
Sitona sp.....	98
Hypera punctata.....	1244
Phytonomus meles.....	3
Phytonomus nigrirostris.....	75
Phytonomus sp.....	43
Listronotus inaequalipennis.....	1
Listronotus frontalis.....	1
Listronotus sp.....	1
Hyperodes sp.....	37
Pachylobius plicivorus.....	1
Lixus sp.....	2
Smicronyx corniculatus.....	1
Bagous sp.....	

TABLE IV.—*List of items identified in the food contained in 2,626 starling stomachs examined, and the number of stomachs in which each was found—Continued.*

ANIMAL MATTER—Continued.

RHYNCHOPHORA—Continued.

Curculionidæ—Continued.

Conotrachelus sp.	1
Acalles sp.	1
Tyloderma foveolatum.	2
Tyloderma aerea.	4
Tyloderma sp.	2
Cryptorhynchus obliquus.	1
Cryptorhynchus fallax.	1
Cryptorhynchus tristis.	1
Cryptorhynchus sp.	1
Centorhynchus sp.	1
Rhinoncus pyrrhopus.	19
Rhinoncus longulus.	1
Rhinoncus sp.	4
Sphenophorus inaequalis.	5
Sphenophorus pertinax.	1
Sphenophorus costipennis.	1
Sphenophorus melanocephalus.	1
Sphenophorus parvulus.	110
Sphenophorus zeae.	26
Sphenophorus sp.	117

HYMENOPTERA (ANTS, BEES, AND WASPS.)

Unidentified hymenopterans.	172
Hymenopterous cocoons.	4
Tenthredinoidea (sawflies):	
Unidentified adults.	1
Unidentified larvæ.	4
Arge dulciaria.	1
Schizocerus zabriskiei.	1
Xiphydria maculata.	1
Ichneumonoidea (parasitic wasps):	
Unidentified.	9
Braconid (unidentified).	1
Apanteles forbesi.	1
Meteorus sp.	1
Chelonella sp.	1
Aleiodes intermedius.	1
Aleiodes sp.	2
Capitonus sp.	1
Cymodusa distincta.	3
Paniscus geminatus.	1
Therion morio.	1
Homoptropus sp.	1
Scambus sp.	1
Pimplidia pedalis.	1
Pimplidia sp.	1
Itopectis conquisitor.	1
Rhyssa sp.	1
Arotes amoenus.	1
Itamoplex limatus.	2
Itamoplex sp.	5
Gambrus sp.	1
Phygadeuon sp.	3
Hemiteles sp.	4
Phaeogenes sp.	19
Amblyteles sp.	1
Cratichneumon sp.	24
Pterocormus seminiger.	1
Pterocormus sp.	19
Pseudamblyteles suturalis.	1
Pseudamblyteles sp.	1

HYMENOPTERA—Continued.

Cynipoidea (gallflies):

Figites sp.	3
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Formicoidea (ants):

Unidentified.	374
Crematogaster lineolata.	2
Aphaenogaster mariae.	1
Aphaenogaster fulva subsp.	11
Aphaenogaster fulva aquia.	4
Aphaenogaster sp.	44
Myrmica punctiventris.	1
Myrmica rubra scabrinodis.	115
Myrmica sp.	45
Lasius niger americanus.	12
Lasius niger neoniger.	2
Lasius umbratus mixtus.	2
Lasius umbratus mixtus aphidicola.	2
Lasius claviger.	2
Lasius latipes.	1
Lasius sp.	11
Formica truncicola integra.	1
Formica pallide-fulva.	4
Formica pallide-fulva var. schaufussi.	37
Formica fusca subsericea.	62
Formica sp.	39
Camponotus herculeanus pennsylvanicus.	34
Camponotus sp.	27

Chrysidioidea (cuckoo wasps):

Chrysis caeruleans.	1
Holopyga sp.	2

Vespoidea (wasps):

Unidentified.	2
Gonatopus sp.	1
Tiphia waldeni.	1
Tiphia inornata.	2
Tiphia egregia.	1
Tiphia transversa.	1
Tiphia sp.	22
Mutillid.	1
Psammochares sp.	3
Odynerus sp.	1
Vespula maculata.	1
Vespula vulgaris.	2
Vespula marginata.	1
Polistes pallipes.	4

Sphecoidea (wasps):

Didineis texana.	1
Cerceris sp.	2
Halictus lerouxi.	2
Halictus sp.	1
Chloralictus pilosus.	4
Chloralictus zephyrus.	2
Chloralictus obscurus.	1
Chloralictus sp.	13
Augochlora confusa.	1
Augochlora sp.	1
Sphecodes sp.	1
Ptilandrena krigiana.	1
Andrena brunniventris rhodura.	3
Andrena forbesi.	1
Andrena frigida.	1
Andrena sp.	4
Osmia sp.	1

TABLE IV.—*List of items identified in the food contained in 2,626 starling stomachs examined, and the number of stomachs in which each was found—Continued.*

ANIMAL MATTER—Continued.

HEMIPTERA (TRUE BUGS).		HEMIPTERA—Continued.	
Unidentified bugs.....	92	Cercopidae (spittle insects):	
Cydnidae (negro bugs):		Philænus sp.....	1
Thyreocoris ater.....	1	Membracidae (tree hoppers):	
Thyreocoris unicolor.....	1	Ceresa diceros.....	1
Thyreocoris sp.....	8	Ceresa sp.....	1
Amnestus spinifrons.....	2	Campylenchia latipes.....	3
Pentatomidae (stinkbugs):		Cicadellidae (leaf hoppers):	
Unidentified.....	320	Unidentified.....	56
Podops cinctipes.....	1	Agallia 4-punctata.....	1
Brochymena sp.....	3	Agallia sanguinolenta.....	2
Mormidea lugens.....	1	Agallia sp.....	1
Euschistus servus.....	1	Draeculacephala mollipes.....	1
Euschistus euschistoides.....	1	Gypona sp.....	1
Euschistus variolarius.....	7	Xerophleba viridis.....	1
Euschistus sp.....	9	Acucephalus albifrons.....	9
Cœnus delius.....	32	Dectocephalus sp.....	2
Thyanta custator.....	1	Fulgoridae (lanternflies):	
Acrosternum hilaris.....	1	Unidentified.....	2
Stiretrus anchorago.....	1	Scolops sp.....	4
Mineus strigipes.....	1	Acanalonia bivittata.....	1
Podisus maculiventris.....	1	ORTHOPTERA (GRASSHOPPERS, LOCUSTS, CRICKETS,	
Coreidae (squash bugs):		(ETC.).	
Unidentified.....	3	Unidentified adults.....	16
Anasa tristis.....	1	Unidentified eggs.....	10
Anasa repetita.....	1	Forficulidae (earwigs):	
Alydus eurinus.....	3	Unidentified.....	1
Alydus sp.....	2	Acrididae (short-horned grasshoppers):	
Lygaeidae (chinchbugs):		Unidentified.....	760
Unidentified.....	39	Nomotettix cristatus.....	2
Blissus leucopterus.....	5	Nomotettix sp.....	1
Isthmocoris piceus.....	12	Tettix arenosus.....	1
Isthmocoris sp.....	2	Tettigidea parvipennis.....	1
Phlegyas sp.....	2	Tettigidea lateralis.....	1
Myodocha serripes.....	9	Tettigidea lateralis var. polymorpha.....	1
Ligyrocoris sp.....	1	Tettigidea sp.....	8
Perigenes sp.....	1	Orphulella olivacea.....	1
Cryphula parallelogramma.....	1	Stenobothrus curtippennis.....	1
Reduviidae (assassin bugs):		Arphia sulphurea.....	1
Unidentified.....	16	Arphia xanthoptera.....	1
Melanolestes picipes.....	2	Chortophaga viridifasciata.....	3
Melanolestes sp.....	1	Hippiscus sp.....	1
Acholla multispinosa.....	2	Melanoplus femoratus.....	2
Sinea diadema.....	6	Melanoplus femur-rubrum.....	24
Sinea sp.....	4	Melanoplus atlanis.....	1
Nabidae (damselfly bugs):		Melanoplus sp.....	36
Unidentified.....	14	Locustidae (green grasshoppers):	
Pagasa fusca.....	8	Unidentified.....	54
Nabis subcoleopratus.....	1	Orchelimum sp.....	2
Nabis sp.....	11	Conocephalus sp.....	4
Cimicidae (bedbugs):		Gryllidae (crickets):	
Cimex sp.....	1	Unidentified.....	332
Miridae (leaf bugs):		Gryllotalpa borealis.....	1
Miris dolabratus.....	2	Nemobius fasciatus vittatus.....	2
Lygus pratensis.....	7	Nemobius sp.....	312
Lygus sp.....	2	Gryllus pennsylvanicus.....	4
Neoborus sp.....	1	Gryllus sp.....	223
Cicadidae (cicadas):		Miogryllus sp.....	2
Tibicen sp.....	1		

TABLE IV.—*List of items identified in the food contained in 2,626 starling stomachs examined, and the number of stomachs in which each was found—Continued.*

ANIMAL MATTER—Continued.

LEPIDOPTERA (MOTHS, BUTTERFLIES, CATERPILLARS, ETC.).

Unidentified.....	65
Unidentified eggs.....	1
Unidentified caterpillars.....	812
Unidentified pupæ.....	20
Nymphalidæ (brush-footed butterflies):	
Argynnis cybele (caterpillar).....	1
Arctiidæ (tiger moths):	
Unidentified caterpillar.....	1
Noctuidæ (cutworms):	
Unidentified caterpillars.....	24
Nephelodes violans (caterpillar).....	1
Nephelodes minians (caterpillars).....	22
Cucullia asteroides (caterpillars).....	2
Lasiolepidæ (tent caterpillars):	
Malacosoma americana (caterpillars).....	3
Malacosoma sp. (caterpillars).....	2
Deilephila lineata (caterpillar).....	1

DIPTERA (FLIES AND THEIR MAGGOTS).

Proctacanthus sp.....	1
Sarcophaga sp.....	1
Phormia terræ-novæ.....	1
Musca domestica.....	2
Tipula sp.....	1
Chrysops sp.....	1
Leia sp.....	1

ARACHNIDA (SPIDERS, TICKS, ETC.).

Drassus neglectus.....	1
Pachygnatha sp.....	1
Tetragnatha sp.....	1
Xysticus luctans.....	1
Lycosa carolinensis.....	1
Lycosa helluo.....	1
Lycosa punctulata.....	1

MYRIAPODA (CENTIPEDES AND MILLIPEDES).

Diplopoda (millipeds):	
Unidentified.....	913
Nemasoma minutum.....	1
Julus caeruleocinctus.....	10
Chilopoda (centipedes):	
Unidentified centipedes.....	7

CRUSTACEA (CRUSTACEANS).

Isopoda (wood lice, etc.):	
Unidentified.....	15
Orchestia grillus.....	1
Orchestia sp.....	1
Porcellio laevis.....	2
Porcellio sp.....	1
Armadillidium sp.....	1

MOLLUSCA (SNAILS, ETC.).

Unidentified mollusks.....	71
Nassidæ (basket shells):	
Ilyanassa obsoleta.....	2
Zonitidæ (glassy snails):	
Zonites arboreus.....	5
Gastrodonta suppressa.....	1
Testacellidæ (flesh-eating land snails):	
Cochlicopa lubrica.....	1
Helicidæ (land snails):	
Vallonia sp.....	11
Auriculidæ (ear snails):	
Melampus lineatus.....	28
Littorinidæ (periwinkles):	
Littorina rudis.....	5
Pupillidæ (chrysalis shells):	
Vertigo ovata.....	1

VEGETABLE MATTER.

Unidentified buds.....	2
Unidentified mast.....	15
Unidentified wild fruit.....	184
Vegetable garbage.....	528
Vegetable rubbish.....	21
Pinaceæ:	
Juniperus virginiana (red cedar).....	13
Juniperus sp. (juniper).....	1
Gramineæ:	
Unidentified grass seeds.....	39
Andropogon sorghum (sorghum).....	2
Panicum miliaceum (millet).....	1
Panicum sp. (switchgrass).....	6
Chaetochloa glauca (foxtail).....	11
Chaetochloa sp. (foxtail).....	13
Eragrostis sp. (love grass).....	1
Anthoxanthum odoratum (sweet vernal grass).....	1
Zea mays (corn).....	59
Triticum vulgare (wheat).....	15
Avena sativa (oats).....	6

Cyperaceæ:	
Unidentified sedge.....	4
Carex sp. (sedge).....	6
Convallariaceæ:	
Asparagus officinalis (asparagus).....	1
Smilacaceæ:	
Smilax herbacea (carrion flower).....	1
Smilax sp. (greenbriar).....	1
Myricaceæ:	
Myrica carolinensis (bayberry).....	122
Betulaceæ:	
Alnus sp. (alder).....	1
Ulmaceæ:	
Celtis occidentalis (hackberry).....	9
Moraceæ:	
Morus alba (white mulberry).....	45
Morus rubra (red mulberry).....	52
Morus sp. (mulberry).....	76
Polygonaceæ:	
Rumex sp. (dock).....	8
Polygonum lapathifolium (smartweed).....	1

TABLE IV.—*List of items identified in the food contained in 2,626 starling stomachs examined, and the number of stomachs in which each was found—Continued.*

VEGETABLE MATTER—Continued.

Polygonaceæ—Continued.		Fabaceæ:	
Polygonum pennsylvanicum (smartweed).....	2	Trifolium sp. (clover).....	3
Polygonum persicaria (smartweed).....	1	Robinia pseudacacia (locust).....	2
Polygonum sp. (smartweed).....	12	Anacardiaceæ:	
Chenopodiaceæ:		Rhus glabra (smooth sumac).....	32
Chenopodium sp. (pigweed).....	1	Rhus copallina (dwarf sumac).....	1
Amaranthaceæ:		Rhus radicans (poison ivy).....	89
Amaranthus sp. (amaranth).....	1	Rhus vernix (poison oak).....	1
Aizoaceæ:		Rhus sp. (sumac).....	266
Mollugo verticillata (Indian chickweed).....	1	Aquifoliaceæ:	
Phytolaccaceæ:		Ilex verticillata (black alder).....	2
Phytolacca decandra (pokeweed).....	20	Celastraceæ:	
Caryophyllaceæ:		Celastrus scandens (bittersweet).....	4
Silene media (chickweed).....	2	Vitaceæ:	
Berberidaceæ:		Pseodera quinquefolia (Virginia creeper).....	39
Berberis vulgaris (barberry).....	1	Ampelopsis sp. (?) (ampelopsis).....	2
Berberis sp. (barberry).....	3	Vitis sp. (grape).....	26
Lauraceæ:		Cornaceæ:	
Sassafras sassafras (sassafras).....	3	Cornus florida (flowering dogwood).....	4
Brassicaceæ:		Cornus amomum (kinnikinnik).....	1
Brassica sp. (mustard).....	1	Cornus asperifolia (rough-leaved dogwood).....	1
Grossulariaceæ:		Cornus paniculata (panicled dogwood).....	1
Ribes sp. (currant).....	1	Cornus sp. (dogwood).....	3
Rosaceæ:		Nyssa sylvatica (sour gum).....	44
Fragaria sp. (strawberry).....	8	Ericaceæ:	
Rubus sp. (blackberry).....	27	Gaylussacia frondosa (huckleberry).....	1
Malaceæ:		Gaylussacia baccata (huckleberry).....	3
Sorbus sp. (mountain ash).....	1	Gaylussacia sp. (huckleberry).....	3
Amelanchier sp. (June berry).....	2	Vaccinium sp. (blueberry).....	5
Malus sp. (cultivated apple).....	45	Solanaceæ:	
Pyrus sp. (cultivated pear).....	3	Solanum sp. (nightshade).....	4
Amygdalaceæ:		Plantaginaceæ:	
Prunus serotina (wild black cherry).....	207	Plantago lanceolata (ribgrass).....	1
Prunus virginiana (chokecherry).....	18	Plantago sp. (plantain).....	5
Prunus maritima (beach plum).....	1	Caprifoliaceæ:	
Prunus sp. (cultivated cherry).....	469	Viburnum sp. (arrowwood).....	19
Prunus sp. (wild cherry).....	62	Sambucus canadensis (elder).....	148
Cassiacæ:		Compositæ:	
Gleditsia triacanthos (honey locust).....	1	Ambrosia artemisiifolia (ragweed).....	29
		Taraxacum taraxacum (dandelion).....	4

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BULLETIN No. 869

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

September 30, 1920

THE INHERITANCE OF THE LENGTH OF INTERNODE IN THE RACHIS OF THE BARLEY SPIKE.

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SCOPE OF THE EXPERIMENTS.

In 1915 a series of studies on the inheritance of the length of internode in the rachis of the barley spike was begun in cooperation with the Minnesota Agricultural Experiment Station. Internode length is a particularly favorable character for such investigations, as a large number of varieties furnish many gradations in internode length and in a pure line the average internode length of the rachis varies comparatively little from year to year.

The project was undertaken for two main reasons, (1) as a study of inheritance in an unusually favorable size character and (2) as a contribution to the question of the taxonomic value of the length of internode of the rachis.

HISTORICAL REVIEW.

The length of internode is frequently referred to as density, and both terms are used in this bulletin. As far back as Linnæus, species were differentiated by this character. With fertility, it has been, consciously or unconsciously, one of the main bases of classification

of most of the modern taxonomists as well. The groups of Schuebler (22)¹, Seringe (23), Heuzé (11, 12), Voss (25), Koernicke (13, 14, 15, 16, 17), Atterberg (2, 3, 4), and Beaven (5) involved variations in density. In 1918 Harlan (10) offered an arrangement which eliminated the question of density from the major groups. It was retained as a minor distinction only, because of the volume of the literature in which it had been used. Its complete elimination would have left too little connection between the author's scheme and the previous usage.

In classifying barleys, density is an obvious and attractive character. When confined to type forms the separations are ideal, but, as with many things in taxonomy, its perfection depends on limited material. The more material that is assembled the more the subdivisions of density have to be increased. Linnæus (18) used the name *Hordeum distichon* to designate the lax 2-rowed and *H. zeocriton* to designate the very dense 2-rowed forms. Schuebler divided *H. distichon* into *erectum* and *nutans*. Eriksson (8) used *genuinum* and *patens* to designate lax and dense subdivisions of *erectum*. Linnæus recognized *hexastichum* and *vulgare* as the dense and lax groups of 6-rowed barleys. Koernicke divided *hexastichum* into *pyramidatum* and *parallelum* and recognized *brachyurum* and *macroterium* of Alefeld (1) as dense and lax subdivisions of *pyramidatum*. The finer the groups were made, the more confusing became the distinctions. The confusion indicated that, while there might be some genetic distinctions, from a taxonomic standpoint there was no clear separation.

In the mode of inheritance the situation is also complicated. As a size character, the accounts are quite favorable as to its constancy, and some varieties are traceable for centuries by this character alone. In recent times Blaringhem (7), possibly following the lead of the Svalof station, made quite elaborate studies of barley density in France. Harlan (9) found density to be quite a stable character. Regarding the mode of inheritance, the studies, however, are largely unsatisfactory. The taxonomic papers contain no comprehensive measurement of density. Many of the inheritance papers are equally inadequate. In many instances fertility and density are treated together, as by Von Tschermak (24). Density has been regarded as recessive by Blaringhem (7) and as dominant by Von Tschermak.

The only paper which is directly concerned with the method of study used in this article is that of Biffen (6), who obtained results closely parallel to those presented herein. In three crosses to which he paid particular attention, Biffen found the F_1 generation to be slightly more dense than the lax parent, although the numbers of individuals in F_1 were small. The F_2 generation consisted in each case of plants

¹ The serial numbers in parentheses refer to "Literature cited," at the end of this bulletin.

with spikes as lax or as dense as those of the parents, with a series lying between these extremes which could not be satisfactorily classified without further test. In some crosses the F_2 generation curves plotted from the measurements showed two peaks and in others three. In a cross of *zeocriton* $\times$ *nutans* groups of plants were centered about internode lengths of 2.2 and 3 millimeters, respectively. The 65 plants constituting the more dense group were tested in the F_3 generation by seeding all individuals with internode lengths ranging from 1.8 to 2.6 millimeters. Of these 65 plants, 55 proved homozygous and 10 were heterozygous. Thus, 55 out of a total of 209 plants grown in F_2 bred true for densities near that of the dense parent, or a close approximation of a 1:3 ratio. No genetic analysis is given of crosses which appear to have three groups in F_2 , or lax, dense, and intermediate forms.

Study has been made of the inheritance of density in wheat and, although apparently pertinent, it is not comparable to one made in barley, for the reason that the dense wheats are clubbed at the tip and thus introduce a condition which makes comparison difficult. Gradations were found in F_2 between the parents. Nilsson-Ehle (20) explained these on the basis of two kinds of factors, a positive factor for compactness which partially inhibited the action of one or more lengthening factors. Parker (21), in a more extensive study in which the statistical method was used, concludes that numbers such as Nilsson-Ehle used were inadequate to demonstrate his hypothesis. In Parker's studies segregation occurred in F_2 , but it seemed impossible to determine the number of factors involved.

PURE-LINE VARIETIES USED IN THESE STUDIES.

With the exception of the Jet variety, the pure lines used in crosses in the studies here reported are quite typical representatives of the three degrees of density much used by taxonomists in the 6-rowed barley. Their relationships are most easily made apparent by use of the taxonomic key which follows. The variations in density are well shown in Plate I.

KEY TO BARLEY VARIETIES USED IN DENSITY STUDIES.

Hordeum vulgare pallidum (6-rowed, hulled, awned, white).

Subvariety *typica*, spike lax, pure-line Manchuria.

Subvariety *parallelum*, spike dense, pure-line Reid Triumph.

Subvariety *pyramidatum*, spike very dense, pure-line Pyramidatum.

Hordeum distichon palmella (2-rowed, hulled, awned).

Subvariety *nutans*, spike lax, pure lines Hanna and Steigum.

Subvariety *erectum*, spike dense, pure-line Svanhals.

Subvariety *zeocriton*, spike very dense, pure-line Zeocriton.

Jet is a naked, black, 2-rowed barley of about the same spike density as Steigum. Although Hanna and Steigum belong to the same group, Steigum is slightly more dense than Hanna. *Deficiens*

was not used in any of the crosses, but is included because of an inherited variation found in it. The form used is lax and differs from *nutans* in having only rudiments of lateral florets.

RELIABILITY OF EXPERIMENTAL METHODS.

In this investigation the feasibility and accuracy of density determinations were tested in many ways. The length of internode was computed from the measurement of 10 internodes in the middle of the spike. All measurements were taken in millimeters.

To test the observational accuracy, the populations from which the density of three parents was determined were remeasured after a lapse of three weeks. The difference in the measurements of Manchuria was 0.02 ± 0.01 mm.; of Zeocriton, 0.04 ± 0.01 mm.; and of Hanna, 0.12 ± 0.02 mm. Differences as small as 0.2 mm. in means of varieties, therefore, can not be demonstrated by the method used. As seasonal fluctuations in the means often are as great as this, the method of taking the data is sufficiently accurate.

The internode measurement was taken in the middle of the spike, not only because of the greater convenience, but because experiments indicated that the internodes in this zone are less variable than in other parts of the spike. Measurements were taken in different parts of the spike on approximately 100 plants of each of the Zeocriton, Pyramidatum, Manchuria, and Hanna parents. Where the spikes were long enough, six different sections were measured, i. e., nodes 1-11, 3-13, 5-15, 7-17, 11-21, and the last 10 internodes toward the tip. In Pyramidatum the measurements for nodes 7-18 and 11-22 could not be made. The means for these measurements, in millimeters, were as follows: Zeocriton, 1.37, 1.47, 1.66, 1.81, 1.95, and 2.15; Pyramidatum, 1.98, 2.12, 2.17, and 2.15; Manchuria, 2.88, 3.13, 3.35, 3.42, 3.36, and 3.38; Hanna, 3.90, 4.17, 4.40, 4.47, 4.35, and 3.90.

The Zeocriton is the only variety in which there is a progressive increase in internode length from the base to the tip. If the factor or factors determining this progressive increase segregate in a normal way, the progeny of a cross between this type and one in which this peculiarity is absent or less pronounced, as in Pyramidatum, might contain types easily misinterpreted. The mean of a pure recessive for a main density factor might easily differ by 0.2 to 0.4 mm. from the parent, due to the gain or loss of this marked progressive increase of internode length found in Zeocriton.

Contrary to results previously reported by Harlan (9), no change in internode length due to the presence of sterile nodes was observed.



AVERAGE HEADS OF THE PARENTAL VARIETIES USED IN THE DENSITY STUDIES.

Left to right: No. 333, Deficiens; 1039, Zeocriton; 458, Svanhals; 17, Steigum; 454, Hanna; 460, Jet; 476, Pyramidatum; 404, Reid Triumph; 360, Manchuria.
(Photographed by Horton.)



AVERAGE HEADS OF THE ZEOCRITON (LEFT), HANNA (RIGHT), AND FOUR HOMOZYGOUS F_3 AND F_4 LINES.

The mean densities are as follows: Zeocriton 448-1, 2.3; 448-5, 2.9; 448-11-3, 3.7; 448-16, 4.3; Hanna, 4.6. All means as given are from 1918 results. (Photographed by Horton.)

EFFECTS OF ENVIRONMENT AND VARYING SOURCES OF SEED ON DENSITY.

Wide differences of condition, such as obtain in California as compared with Minnesota, are sufficient to modify the expression of density. As will be seen by referring to Table I, the annual fluctuations of density measurements in a pure variety are not sufficient in Minnesota to introduce any large error in the conclusions, especially when it is considered that progeny are compared only with parents of the same year's growth.

In 1918 there was an opportunity to test the effect of vigor of plant on density. One section of the nursery produced Manchuria plants which averaged 110 centimeters in height, while the same strain in another part of the nursery averaged only 82 centimeters. A similar difference was apparent in Svanhals. The internode lengths of the Manchuria plants were 3.36 ± 0.01 and 3.33 ± 0.01 mm., respectively, and of Svanhals, 2.56 ± 0.01 and 2.65 ± 0.01 mm., respectively, both being within the limits of observational accuracy.

Sometimes the F_1 generation of a cross was grown in the Washington greenhouse and the seed from it was still rather immature when sown in Minnesota. Plants of Manchuria from greenhouse seed gave a mean internode length of 3.22 ± 0.02 mm., as compared with 3.34 ± 0.02 mm. in plants from field-grown seed. In Svanhals, the difference was less, 2.49 ± 0.02 as compared with 2.52 ± 0.01 mm. Neither variation is large enough to have any particular significance in this study.

PURITY OF PARENTAL FORMS.

The variation which may be expected in a pure line within a single season and from season to season is shown in Table I. The 6-rowed varieties gave about the same mean average length of internode in all three seasons. With the 2-rowed varieties there was more seasonal fluctuation in average density. All varieties of this group gave a higher mean length of internode in 1918 than in 1917. In Steigum the seasonal difference reached its maximum of 0.51 ± 0.03 mm., and in Hanna the seasonal variation also was large. Individuals of different densities in the different varieties were selected as parents. The only possibility of inherited variation within the same variety occurred in *deficiens*. The progeny of plant 333-5-1 is significantly lower in mean density. Only two or three *deficiens* types have been grown in the nursery, and the progeny showed no evidence of hybridization. As the chance of mixture or accidental crossing is small, it might be interpreted that we had chanced to select a spike in which a sudden change in the factors for density had taken place.

[illegible]

TABLE I.—Record of spike density in pure-line barley parents and in their progeny—Continued.

[illegible]

INHERITANCE OF LENGTH OF INTERNODES IN CROSSES BETWEEN PURE LINES.

Each cross studied has been considered as a separate family. For convenience, the data from each such family will be discussed separately. In considering crosses, statements will be made as to the number of homozygous and heterozygous forms. Such statements can be only relative. Using the variability of the pure lines as a standard, it is assumed that progeny lines of low variability are homozygous, while those of high variability are heterozygous. There is no reasonable doubt of the classification of the extremes, but there is a borderland where the most varying homozygotes may be in doubt.

FAMILY MANCHURIA (360) $\times$ SVANHALS (458).

The actual F_1 generation of the cross between Manchuria and Svanhals, which was the basis of later generations discussed in this bulletin, was grown in 1915. A considerable number of crosses between these same pure lines of Manchuria and Svanhals were made in 1917 in the greenhouse at Washington, D. C. The data for the F_1 reported in Table II (sec. A) are from this greenhouse seed. On the basis of the coefficient of variability, this F_1 generation proved no more variable than the parents.

In 1917 the mean average density in millimeters of the Svanhals parent was 2.53 ± 0.01 mm.; of the Manchuria, 3.34 ± 0.01 mm.; and of the F_1 , 2.70 ± 0.01 mm. There is almost a complete dominance of the dense over the lax form.

An F_2 generation was grown both in 1916 and in 1918. The means for these two F_2 generations were 2.94 ± 0.01 and 2.96 ± 0.02 mm., respectively. The variation as determined by the frequency distribution and the coefficient of variability was much greater in F_2 than in F_1 or in the parental forms, the coefficient of variability of the F_1 generation being 6.30 ± 0.30 mm. and of the F_2 generations of 1916 and 1918, 10.20 ± 0.27 and 11.82 ± 0.48 mm., respectively.

Thirty-two F_3 lines, representing all F_2 types of density, were grown. Thirteen of these F_2 plants appeared to give homozygous progeny in the F_3 generation. The writers recognize that too few plants were grown in F_3 to determine with certainty which forms were homozygous. Eight of these 13 lines were continued in F_4 , and five of these appeared to be homozygous. These results show that a considerable number of the F_2 plants selected bred true in F_3 , although no conclusion as to the actual percentage can be made.

The five types which proved to be homozygous in F_4 gave mean densities as follows: 378-1, mean 2.57 ± 0.01 mm.; 378-11, mean 2.64 ± 0.01 mm.; 378-14, mean 3.37 ± 0.02 mm.; 378-23, mean 2.55 ± 0.01 mm.; 378-31, mean 2.58 ± 0.01 mm. Selection 378-88 gave the highest coefficient of any third-generation line. Two heads were selected which bred true in F_4 for densities near the Manchuria parent.

TABLE II.—Record of spike density in parent pure lines of barley varieties and in successive generations of their progeny.

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Sec.	D.	Hanna (400) × Reid Tri- umpon (404) = 406: Hanna 460.....	P ₁ 1916 3.6 to 4.9 Do. 4.1 to 4.7	P ₂ 1917 Do.	P ₃ 1918 Do.	P ₄ 1919 Do.	P ₅ 1920 Do.	P ₆ 1921 Do.	P ₇ 1922 Do.	P ₈ 1923 Do.	P ₉ 1924 Do.	P ₁₀ 1925 Do.	P ₁₁ 1926 Do.	P ₁₂ 1927 Do.	P ₁₃ 1928 Do.	P ₁₄ 1929 Do.	P ₁₅ 1930 Do.	P ₁₆ 1931 Do.	P ₁₇ 1932 Do.	P ₁₈ 1933 Do.	P ₁₉ 1934 Do.	P ₂₀ 1935 Do.	P ₂₁ 1936 Do.	P ₂₂ 1937 Do.	P ₂₃ 1938 Do.	P ₂₄ 1939 Do.	P ₂₅ 1940 Do.	P ₂₆ 1941 Do.	P ₂₇ 1942 Do.	P ₂₈ 1943 Do.	P ₂₉ 1944 Do.	P ₃₀ 1945 Do.	P ₃₁ 1946 Do.	P ₃₂ 1947 Do.	P ₃₃ 1948 Do.	P ₃₄ 1949 Do.	P ₃₅ 1950 Do.	P ₃₆ 1951 Do.	P ₃₇ 1952 Do.	P ₃₈ 1953 Do.	P ₃₉ 1954 Do.	P ₄₀ 1955 Do.	P ₄₁ 1956 Do.	P ₄₂ 1957 Do.	P ₄₃ 1958 Do.	P ₄₄ 1959 Do.	P ₄₅ 1960 Do.	P ₄₆ 1961 Do.	P ₄₇ 1962 Do.	P ₄₈ 1963 Do.	P ₄₉ 1964 Do.	P ₅₀ 1965 Do.	P ₅₁ 1966 Do.	P ₅₂ 1967 Do.	P ₅₃ 1968 Do.	P ₅₄ 1969 Do.	P ₅₅ 1970 Do.	P ₅₆ 1971 Do.	P ₅₇ 1972 Do.	P ₅₈ 1973 Do.	P ₅₉ 1974 Do.	P ₆₀ 1975 Do.	P ₆₁ 1976 Do.	P ₆₂ 1977 Do.	P ₆₃ 1978 Do.	P ₆₄ 1979 Do.	P ₆₅ 1980 Do.	P ₆₆ 1981 Do.	P ₆₇ 1982 Do.	P ₆₈ 1983 Do.	P ₆₉ 1984 Do.	P ₇₀ 1985 Do.	P ₇₁ 1986 Do.	P ₇₂ 1987 Do.	P ₇₃ 1988 Do.	P ₇₄ 1989 Do.	P ₇₅ 1990 Do.	P ₇₆ 1991 Do.	P ₇₇ 1992 Do.	P ₇₈ 1993 Do.	P ₇₉ 1994 Do.	P ₈₀ 1995 Do.	P ₈₁ 1996 Do.	P ₈₂ 1997 Do.	P ₈₃ 1998 Do.	P ₈₄ 1999 Do.	P ₈₅ 2000 Do.	P ₈₆ 2001 Do.	P ₈₇ 2002 Do.	P ₈₈ 2003 Do.	P ₈₉ 2004 Do.	P ₉₀ 2005 Do.	P ₉₁ 2006 Do.	P ₉₂ 2007 Do.	P ₉₃ 2008 Do.	P ₉₄ 2009 Do.	P ₉₅ 2010 Do.	P ₉₆ 2011 Do.	P ₉₇ 2012 Do.	P ₉₈ 2013 Do.	P ₉₉ 2014 Do.	P ₁₀₀ 2015 Do.	P ₁₀₁ 2016 Do.	P ₁₀₂ 2017 Do.	P ₁₀₃ 2018 Do.	P ₁₀₄ 2019 Do.	P ₁₀₅ 2020 Do.	P ₁₀₆ 2021 Do.	P ₁₀₇ 2022 Do.	P ₁₀₈ 2023 Do.	P ₁₀₉ 2024 Do.	P ₁₁₀ 2025 Do.	P ₁₁₁ 2026 Do.	P ₁₁₂ 2027 Do.	P ₁₁₃ 2028 Do.	P ₁₁₄ 2029 Do.	P ₁₁₅ 2030 Do.	P ₁₁₆ 2031 Do.	P ₁₁₇ 2032 Do.	P ₁₁₈ 2033 Do.	P ₁₁₉ 2034 Do.	P ₁₂₀ 2035 Do.	P ₁₂₁ 2036 Do.	P ₁₂₂ 2037 Do.	P ₁₂₃ 2038 Do.	P ₁₂₄ 2039 Do.	P ₁₂₅ 2040 Do.	P ₁₂₆ 2041 Do.	P ₁₂₇ 2042 Do.	P ₁₂₈ 2043 Do.	P ₁₂₉ 2044 Do.	P ₁₃₀ 2045 Do.	P ₁₃₁ 2046 Do.	P ₁₃₂ 2047 Do.	P ₁₃₃ 2048 Do.	P ₁₃₄ 2049 Do.	P ₁₃₅ 2050 Do.	P ₁₃₆ 2051 Do.	P ₁₃₇ 2052 Do.	P ₁₃₈ 2053 Do.	P ₁₃₉ 2054 Do.	P ₁₄₀ 2055 Do.	P ₁₄₁ 2056 Do.	P ₁₄₂ 2057 Do.	P ₁₄₃ 2058 Do.	P ₁₄₄ 2059 Do.	P ₁₄₅ 2060 Do.	P ₁₄₆ 2061 Do.	P ₁₄₇ 2062 Do.	P ₁₄₈ 2063 Do.	P ₁₄₉ 2064 Do.	P ₁₅₀ 2065 Do.	P ₁₅₁ 2066 Do.	P ₁₅₂ 2067 Do.	P ₁₅₃ 2068 Do.	P ₁₅₄ 2069 Do.	P ₁₅₅ 2070 Do.	P ₁₅₆ 2071 Do.	P ₁₅₇ 2072 Do.	P ₁₅₈ 2073 Do.	P ₁₅₉ 2074 Do.	P ₁₆₀ 2075 Do.	P ₁₆₁ 2076 Do.	P ₁₆₂ 2077 Do.	P ₁₆₃ 2078 Do.	P ₁₆₄ 2079 Do.	P ₁₆₅ 2080 Do.	P ₁₆₆ 2081 Do.	P ₁₆₇ 2082 Do.	P ₁₆₈ 2083 Do.	P ₁₆₉ 2084 Do.	P ₁₇₀ 2085 Do.	P ₁₇₁ 2086 Do.	P ₁₇₂
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TABLE II.—Record of spike density in parent pure lines of barley varieties and in successive generations of their progeny—Continued.

[illegible]

The Svanhals parent gave a mean of 2.71 ± 0.01 mm. and the Manchuria one of 3.46 ± 0.01 mm. in 1918. No sorts were obtained which were homozygous for densities very different from those of the parents.

FAMILY MANCHURIA (360) $\times$ STEIGUM (17).

The parental forms of the Manchuria and Steigum cross gave nearly the same average density in 1916. In 1918 the Manchuria parent gave about the same average density as in 1916, but the Steigum averaged somewhat higher than in the previous year. The coefficient of variability of the Manchuria parent in 1917 was 4.19 ± 0.15 mm.; of the Steigum parent, 4.90 ± 0.17 mm.; and of the F_2 generation which was grown in 1916, 7.69 ± 0.21 mm. The data are reported in Table II (sec. B).

As Table II shows, some forms bred true in F_3 and in F_4 , while others were as variable as the F_2 generation. Selection 368-22 in the F_3 and F_4 generations gave means of 3.21 ± 0.02 and 3.29 ± 0.01 mm., respectively. When compared with the parental forms, it seems that we have here a lower density line than either parent. As the number of individuals is small in many F_3 lines, it does not seem profitable to analyze more closely the results obtained.

FAMILY PYRAMIDATUM (476) $\times$ JET (454).

Table II (sec. C) shows that the parental forms of the cross between Pyramidatum and Jet are of very different densities. The Pyramidatum parent gave a mean density of 2.11 ± 0.01 mm. in 1918; the Jet, 3.92 ± 0.01 mm.; while the F_1 generation averaged 2.86 ± 0.01 mm. The F_1 generation is, therefore, slightly more dense than the parental average, which is 3.01 mm. This is quite different from the F_1 generation in the cross between Manchuria and Svanhals, in which there was an almost complete dominance of the dense over the lax form.

The F_2 generations were grown both in 1916 and in 1918. The means for these two F_2 generations were about the same as the parental average, being 2.92 ± 0.04 mm. and 3.10 ± 0.03 mm., respectively. The highest coefficient of variability for the Jet parent is 6.93 ± 0.39 mm., while the highest coefficient for Pyramidatum is 6.16 ± 0.21 mm. The coefficients of variability for the two F_2 generations are 16.44 ± 0.87 mm. and 18.38 ± 0.81 mm., respectively, while the frequencies of the F_2 generations range from above the modal class of the lax parent to the modal class of the dense parent. It is of interest to note that with a total of 87 F_1 plants, none were of the same frequency range as that of the parents, all being of intermediate density. Of the 22 F_2 plants continued in F_3 , ten would have been included within the limits of this F_1 population. Of these ten, eight gave about as variable a progeny as the F_2 generation, while two

appeared to give homozygous dense progeny. Of the entire 22 plants, representing all types of F_2 densities, nine proved about as variable in F_3 as the F_2 generation.

Seven F_3 selections which appeared to be breeding true, as determined by the frequency distribution and coefficient of variability, were tested in the F_4 generation. This was done by selecting 10 heads of different densities and growing the progeny of each separately. Where all heads gave similar results, they are combined in the table and are given as the result of 10 plants.

The F_3 line 325-5, of which only 26 plants were available for study, gave a mean of 3.15 ± 0.02 mm. in 1917, with a low coefficient of variability. On testing this line in 1918, when data from 213 plants were available, a somewhat higher mean was obtained, or 3.43 ± 0.01 mm. Its coefficient of variability is also somewhat larger than in the homozygous parental forms. Selection 325-15 proved pure in F_4 with the exception of the progeny of one plant which gave as great a variability as the F_2 generation. Why one plant should behave so differently from the nine others is difficult to explain. The possibility of a natural cross must not be overlooked, although observations show that these are very infrequent. An occasional error is also a possibility, although precautions were taken to eliminate these as far as possible.

The F_4 means for the seven lines which gave evidence in F_3 and F_4 indicating that they were homozygous are as follows: 325-5 (10 plants), 3.43 ± 0.01 mm.; 325-13 (10 plants), 3.47 ± 0.01 mm.; 325-16 (9 plants), 3.74 ± 0.01 mm.; 325-18 (10 plants), 2.24 ± 0.01 mm.; 325-20 (10 plants), 2.47 ± 0.02 mm.; 325-21 (10 plants), 3.95 ± 0.01 mm.; 325-22 (10 plants), 3.72 ± 0.01 mm.

Of these, five have mean densities which are not very different from that of the Jet (lax) parent, while the means of the other two are similar to that of the Pyramidatum parent. The most dense and the least dense of the five lax homozygous segregates have mean internode lengths of 3.43 ± 0.01 mm. and 3.95 ± 0.01 mm., respectively. As great a difference as this in any one season would not be expected in a sort homozygous for similar characters. It is not much greater, however, than seasonal variation in the means of several of the pure 2-rowed forms, which seem more susceptible to such variability than the 6-rowed parents. Inheritance of such a reaction difference might possibly explain the results here represented. Whatever explanation may be given for these new means, here, as in the Manchuria $\times$ Svanhals cross, no homozygous forms were produced which differed materially in density from the density of one or the other parent.

FAMILY HANNA (460) $\times$ REID TRIUMPH (404).

The parental forms, Hanna and Reid Triumph, are of distinctly different densities, and there is no overlapping of frequency distributions during the three years in which they have been grown. In Table II (sec. D) the mean of the Hanna parent ranges from 4.12 ± 0.02 mm. in 1916 to 4.56 ± 0.01 mm. in 1918. The Reid Triumph variety has much less seasonal variation, the mean in 1917 being 2.73 ± 0.01 mm. and in 1916, 2.64 ± 0.01 mm. It is of interest to note that the Reid Triumph has about the same average mean as the Svanhals 2-rowed form, while the Hanna is considerably more lax than the Manchuria form which was crossed with the Svanhals variety.

The F_2 generation of the cross between Hanna and Reid Triumph proved more variable than the parents and frequently gave distribution from below the mode of the Reid Triumph to considerably above the mode of the Hanna parent. Twenty F_2 plants were grown in F_3 , some giving as variable a population as obtained in F_2 , while other F_3 lines were no more variable than the parental forms.

Fourteen of these F_3 lines which gave the clearest indication of being homozygous were further tested in the F_4 generation. The method was similar to that previously used, 4 to 10 plants of a line being grown and the combined result being the basis of conclusions as to purity. Of the 14 lines tested in F_4 , 8 gave evidence in the combined F_3 and F_4 data to show that they are homozygous for density.

Those which are of questionable purity will be briefly considered. Selection 406-3 gave a mean of about the same density as the Reid Triumph parent, but the coefficient of variability is somewhat higher than in the pure parental lines. Selection 406-4 proved to be heterozygous. One of the head selections, 406-4-3, produced a type which seems pure for density. The mean of this line is 3.72 ± 0.03 mm. Selection 406-9 seems to be heterozygous. Probably 406-9-1 is homozygous, the average mean being about the same as that of the Hanna parent. Selection 406-10 also is more variable than the pure parental variety. The frequency distribution indicates that fewer density factors are involved than in the F_2 generation. Selections 406-16 and 406-18 appear to be heterozygous. In later generations two selections of 406-18 seem to be homozygous. Thus 406-18-5 is probably breeding true with a mean density of 3.40 ± 0.02 mm., while 406-18-9 gives evidence of being homozygous for a mean of 2.66 ± 0.02 mm.

Those which seem nearly homozygous by an examination of their frequency ranges and coefficients of variability as obtained in F_3 and F_4 generations are as follows: 406-1, mean 2.81 ± 0.01 mm.; 406-5, mean 4.43 ± 0.01 mm.; 406-7, mean 2.43 ± 0.01 mm.; 406-8, mean 4.32 ± 0.01 mm.; 406-11, mean 4.32 ± 0.02 mm.; 406-12, mean,

2.84 $\pm$ 0.02 mm.; 406-19, mean 3.29 $\pm$ 0.01 mm.; 406-22, mean 4.37 $\pm$ 0.01 mm.

Aside from these, individual heads grown in F_4 which appear to give homozygous progeny as a result of the single season's test are as follows: 406-4-3, mean 3.72 $\pm$ 0.03 mm.; 406-9-1, mean 4.30 $\pm$ 0.04 mm.; 406-18-5, mean 3.40 $\pm$ 0.02 mm.; 406-18-9, mean 2.66 $\pm$ 0.02 mm.

The means for these four F_4 families are somewhat unreliable because of the small number of individuals grown. All coefficients of variability, however, are very small.

These results show that homozygous intermediates may be produced, as well as homozygous types, which give about the same average density as the parental forms. No analysis of average differences as small as 0.2 to 0.3 mm. has been attempted. The fact that environmental or other seasonal characters may modify the expression of a character nullifies such close analysis.

FAMILY HANNA (460) $\times$ ZEOCRITON (1039).

The Hanna used in the cross with Zeocriton is the same pure line that was used in the cross with Reid Triumph. Zeocriton is a very dense 2-rowed form. This cross is between the most dense and the most lax form used in this study.

The F_2 generation shown in Table II (sec. E) ranged from above the modal class of Hanna to the modal class of Zeocriton, even though only 141 individuals were studied. It has a correspondingly high coefficient of variability.

An examination of the coefficients obtained in later generations show that some are as large as those obtained in the F_2 line. Others are intermediate, being significantly larger than any obtained in the pure forms, while still others are as small as those obtained for the pure parental lines. This would indicate that the mode of inheritance was more complex than in the cross between *Pyramidatum* $\times$ *Jet* previously mentioned.

Selection 448-9, which was almost as variable in the F_3 as in the F_2 generation, was selected for further experiment, the progeny of 30 plants being measured in the F_4 generation. Data from 7 of the 30 progeny lines are presented, as the remaining 23 all appeared to be segregating. Results of density studies in F_4 lines 448-9-7, 448-9-14, 448-9-16, and 448-9-29 are given, as these indicate the segregation obtained in the unrepresented lines. No F_4 line of greater coefficient of variability than 448-9-7 was obtained, and none with a wider frequency range than 448-9-16. Three lines appear to be homozygous, as determined by the frequency distribution and coefficient of variability. These are shown in Table III.

TABLE III.—*Homozygous plants of selection 448-9 of the Hanna-Zeocriton cross, F₄ generation.*

F ₄ line.	Number of individuals.	Mean.	Coefficient of variability.
		<i>Millimeters.</i>	
448-9-4.....	63	2.06±0.01	6.80±0.41
448-9-19.....	16	3.41±.04	7.33±.87
448-9-30.....	59	4.30±.02	4.65±.29

The mean of 448-9-19 is not as reliable as of the other two lines, as only 16 individuals were available for the study.

Selections 448-7 and 448-13 appear heterozygous in the F₃ generation and have about the same degree of frequency range. The coefficients of variability are much smaller than in F₂, but are significantly larger than in the pure parental forms. The frequency range for 448-7, of which 39 plants were studied, was from 2.0 to 3.2 mm. Two plants from each of these lines gave evidence of being homozygous in F₄. These are shown in Table IV.

TABLE IV.—*Homozygous plants of selections 448-7 and 448-13 of the Hanna-Zeocriton cross, F₄ generation.*

F ₄ line.	Number of individuals.	Mean.	Coefficient of variability.
		<i>Millimeters.</i>	
448-7-1.....	107	2.21±0.01	7.69±0.35
448-7-3.....	102	3.12±.01	5.77±.27
448-13-2.....	64	3.19±.02	6.27±.37
448-13-5.....	57	4.15±.02	4.58±.29

Four of the 20 F₂ plants which were tested in F₃ appeared to give homozygous progeny. Three of these proved to be homozygous by further test, while one, 448-11, proved heterozygous. The F₄ lines of interest which seem to be homozygous are shown in Table V.

TABLE V.—*Homozygous plants of selection 448-11 of the Hanna-Zeocriton cross, F₄ generation.*

F ₄ line.	Number of individuals.	Mean.	Coefficient of variability.
		<i>Millimeters.</i>	
448-11-2.....	73	3.08±0.01	5.52±0.31
448-11-3.....	45	3.69±.02	4.34±.31

The three lines of especial interest which appeared homozygous by both the F₃ and F₄ study are as follows: 448-1, mean 2.30±.01 mm.; 448-5, mean 2.88±.01 mm.; 448-16, mean 4.30±.01 mm. The F₄ generation means are given for these lines, as they are based upon larger numbers than the F₃ test. Typical spikes of the parent varieties and of these lines are shown in Plate II.

In the Hanna $\times$ Zeocriton cross there are a number of homozygotes of a density intermediate between the densities of the parents. The homozygotes of this cross appear to fall in groups. Three near the dense parent have internode lengths ranging from 2.06 to 2.30 mm. Three near the lax parent have internode lengths ranging from 4.15 to 4.30 mm. Four moderately dense intermediates have internode lengths varying from 2.88 to 3.19 mm., and two lax intermediates have internode lengths of 3.41 and 3.69 mm. This grouping is arbitrary, as the difference between the two intermediate groups is little more than between individuals of either intermediate group. Some homozygous intermediates from this cross have densities approximately the same as those of parents used in other crosses studied.

SUMMARY OF RESULTS.

The observational accuracy is such that differences in density greater than 0.2 mm. are significant when the measurements are taken in the middle part of the spike.

Except in the Hanna and Steigum varieties the seasonal fluctuations in the means of the parents were not more than 0.2 mm. The seasonal variations in the means of the 2-rowed were greater than in the 6-rowed varieties.

The density of the F_1 generation does not have an unvarying relation to the density of the parents. In the Svanhals $\times$ Manchuria cross density is dominant in the F_1 generation. In the Pyramidatum $\times$ Jet cross it was intermediate.

The two F_1 generations grown were no more variable than the parental sorts and all crosses gave segregation in F_2 . Although the number of F_2 plants grown averaged no greater than that of the parental forms, the frequency ranges extended from the modal class of one parent to the modal class of the other and often beyond these classes.

The F_3 generation contained progeny groups which were no more variable for length of rachis internode than pure lines of the parents. Rather extensive studies of a number of F_4 generations gave further evidence of purity of several of these F_3 lines.

The Manchuria $\times$ Svanhals and Pyramidum $\times$ Jet crosses gave forms homozygous for densities similar to those of the parents but none homozygous for intermediate densities. Crosses between Hanna and Reid Triumph and between Hanna and Zeocriton gave types homozygous for densities intermediate between the densities of the parents, as well as near those of their parents. The latter cross produced homozygous forms similar to Reid Triumph, Hanna, and their homozygous intermediates, as well as forms like the Zeocriton parent. The range of means of these homozygous forms was almost continuous, although there was an indication of two centers of intermediate

density. More extensive study would be needed to determine whether these apparent centers are of any significance.

DISCUSSION OF RESULTS.

From the fact that segregates homozygous for density are apparent in the measurements of the F_3 and F_4 generations, it seems safe to conclude that internode length in the barley rachis may be explained on the factor hypothesis. The number or value of the factors involved is not readily estimated. In a general way the results of the Manchuria $\times$ Svanhals and the Pyramidatum $\times$ Jet crosses seem to indicate a single main factor difference. The proportion of homozygotes is roughly satisfactory, and the absence of homozygotes differing greatly from the mean of their parents is also in favor of this belief. The dominance of density in the F_1 generation in the first cross and its intermediate expression in the second is of interest.

The results in the Hanna $\times$ Reid Triumph cross in the same way indicate a broad difference of two factors. In this cross forms were isolated that were homozygous for intermediate densities, as well as forms having densities near those of the parents. These results can be interpreted very satisfactorily on the basis of two main factors for internode length. These factors are cumulative in effect, both being necessary to produce the extreme type. The results show that a sort may be homozygous for one of the factors and heterozygous for the other. At least, heterozygous forms whose progeny range is from the intermediate group to one or the other parent are so interpreted.

The Hanna $\times$ Zeocriton cross gave homozygous intermediates of unlike value, as well as homozygous sorts which were like the parents. If the presence and absence hypothesis is here used, three main factors may be postulated to explain the genetic facts. These factors may be supposed to be of like value, each inherited independently, each allelomorphic to its absence, the number showing a heterozygous condition being half the homozygous sorts. This hypothesis explains the genetic fact fairly well. Other minor factor differences are doubtless necessary to explain all of the results. One known minor character of some density significance separates the parental forms. This is a difference in the progressive density from the base to the tip of the rachis, the Zeocriton parent being the only sort which shows a constant increase in length of internode from the base to the tip of the spike.

A comparison of the Pyramidatum $\times$ Jet cross with the Hanna $\times$ Zeocriton cross illustrates some facts regarding the mode of inheritance of density. These are the two widest crosses made in the study. The first produced no homozygous intermediates. The second produced many. An F_1 generation was grown of the Pyramidatum $\times$

Jet cross. It was of intermediate density and no more variable than the parental forms. The second generation is shown in figure 1 as a multimodal curve with peaks at densities corresponding to those of the parents and the F_1 generation. The homozygous forms produced closely approximated the densities of the parental varieties, as is illustrated by the curves. Although there is considerable variability in the means of the more lax segregates, this is no greater than the seasonal variation of the means of several of the 2-rowed forms.

The contrast between the Pyramidatum $\times$ Jet and the Hanna $\times$ Zeocriton crosses is very striking. Each showed wide segregation

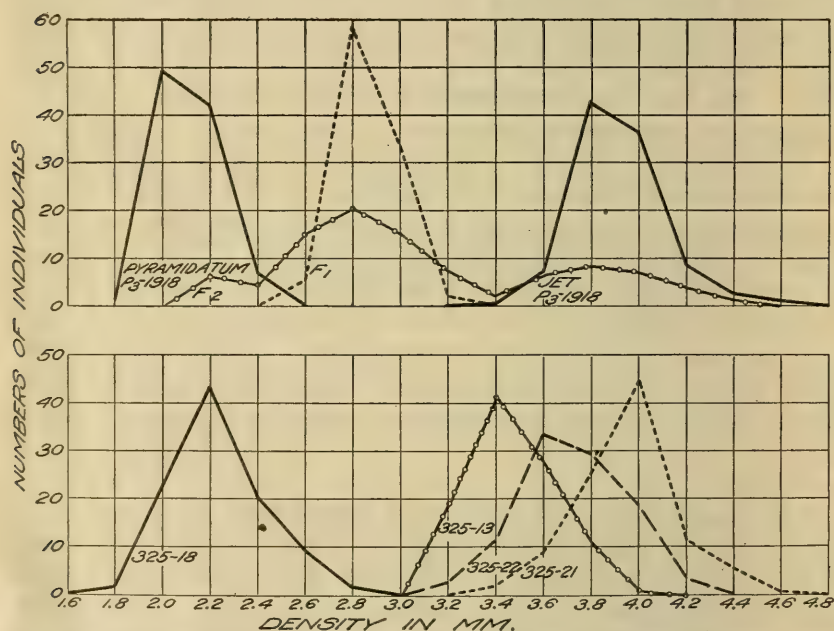


FIG. 1.—Diagrams showing the densities of parental forms and F_1 and F_2 generations of a cross between the Pyramidatum and Jet barleys (upper) and of four homozygous forms from this cross in the F_3 generation (lower).

in the F_2 generation. Hanna $\times$ Zeocriton, however, produced a much smaller proportion of homozygous forms in F_3 and F_4 than the Pyramidatum-Jet cross. Homozygous intermediates as well as forms with the parental densities were produced in the F_3 generation. The heterozygous lines were of different types, some being as variable as the F_2 , while others were more variable than the pure forms, but less so than the F_2 generation. The means of the heterozygous forms were also of different values. The results are illustrated in figure 2. These graphs show the parental and F_2 types and four pure F_3 forms of unlike densities, as well as the heterozygous lines obtained. This cross has given nearly all sorts of densities, and by this one cross the different densities of the parental forms used in these experiments have been again obtained.

These results show that, although density is a very stable size character, in some crosses numerous factors are involved which, by recombination, produce homozygous forms showing an almost continuous range of density from the very lax to the dense types. It is only reasonable to conclude that if a greater number of varieties had been studied, together with crosses between them, a continuous range for the average length of internode of homozygous forms could be obtained which would show only small differences in average density between types. These results are of considerable interest in barley classification. While dependable in the isolation and description of

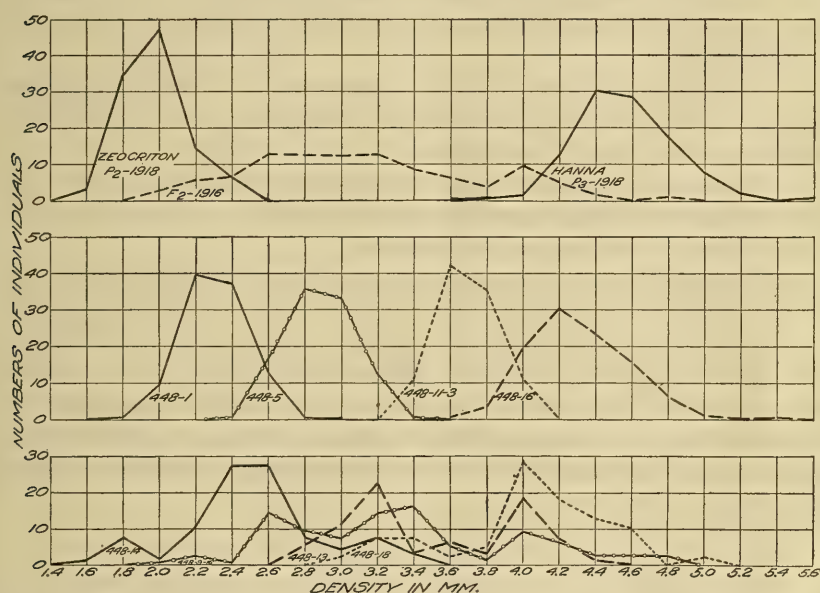


FIG. 2.—Diagrams showing the densities of parental forms and of the F_2 generation in a cross between the Zeocriton and Hanna barleys (upper), of four pure lines (middle), and of several heterozygous lines (lower).

strains, groups founded on this character are likely to overlap and hence to be of limited value for taxonomic purposes.

While the general genetic results of these crosses are explained on a broad factor basis of differences of one to three factors, the fact remains that the homozygous segregates corresponding to the parents do not always have the exact density of the parents. Likewise, the forms homozygous for intermediate densities do not all fall together but in groups, which, in the Hanna $\times$ Zeocriton cross become almost continuous, even where limited numbers are concerned, and might become wholly continuous if it were possible to carry the full number to the fourth generation. Obviously, there are modifying factors, and so far as they affect density they may be considered as minor density factors. Several explanations are possible. These varia-

tions may be associated with the same variability which manifests itself in seasonal fluctuations. They may be due to the differences in the progressive density from the base to the tip of the rachis, which is more marked in some than in other varieties. Other explanations might be suggested, but in the absence of definite proof it seems unwise to attempt a more detailed analysis of the results.

CONCLUSIONS.

Despite the handicaps of the investigations, a number of points are established.

(1) Internode length in the barley rachis is a very stable character, which is much less affected by environmental conditions than many size characters.

(2) Segregation occurs in the F_2 generation of crosses, and forms homozygous for density appear in this generation, their purity being demonstrated in the F_3 generation.

(3) In some crosses new lines with densities differing much from those of their parents can not be secured, while in others lines with very different densities may be isolated.

(4) The inheritance of internode lengths may be interpreted on the factor hypothesis. Some of the crosses studied appeared to differ by a single main factor of density, while in others two or three main factors are necessary to explain the genetic results. Minor factors were evident whose number or nature was not established and through whose action the means of homozygous forms of intermediate densities in some crosses may become more or less continuous between the means of the parents.

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BULLETIN No. 870

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief



Washington, D. C.

October 20, 1920

EFFECT OF WINTER RATIONS ON PASTURE GAINS OF YEARLING STEERS.¹

By E. W. SHEETS and R. H. TUCKWILLER, *Animal Husbandry Division.*²

I. WINTER RATIONS AND THEIR INFLUENCE ON PASTURE GAINS OF YEARLING STEERS.

II. THE USE OF SILAGE AND THE COST OF RATIONS FOR WINTERING YEARLING STEERS.

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OUTLINE OF THE EXPERIMENTAL WORK.

The work reported in this bulletin is part of a series of beef-cattle experiments that have been in progress since December 22, 1914, carried on in cooperation between the Bureau of Animal Industry of the United States Department of Agriculture and the West Virginia Agricultural Experiment Station on the farm of David Tuckwiller,

¹ A report of cooperative work by the Bureau of Animal Industry, United States Department of Agriculture, and the West Virginia Agricultural Experiment Station.

² The authors acknowledge the services of W. F. Ward, formerly of the Animal Husbandry Division, who assisted in planning this experiment, and of F. W. Farley, J. B. Huyett, and E. A. Tuckwiller, formerly of the Animal Husbandry Division, who assisted in carrying on the work.

in Greenbrier County, W. Va., to study beef-production problems in the Appalachian Mountain region. This farm is located in the southeastern part of the State in the blue-grass area. The results of this experiment apply not only to West Virginia but also to the adjacent States having similar conditions, as shown in the outline map (fig. 1). Some of the results and methods may be of such general application as to be utilized to advantage by cattle feeders in other parts of the country.

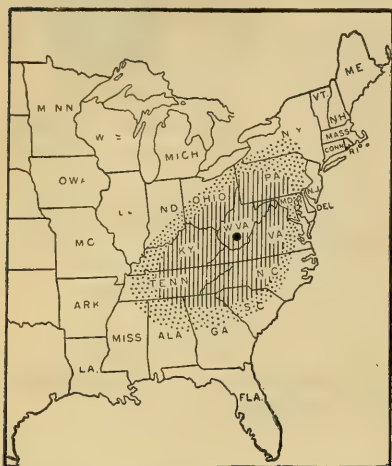


FIG. 1.—Map showing region to which this work applies. The black dot indicates the location of the farm on which the experiment was conducted. The shaded portion represents the area to which the results are applicable, and the dotted portion shows an additional area to which the results apply in part.

THE REGION AND THE PROBLEMS

The topography in most parts of the region, except in the vicinity of streams, is gently rolling or even mountainous in the higher elevations. The area is generally cleared of forest trees, although vast areas of cut-over or stump land are found. The farms vary in size from less than 100 acres to more than 1,000 acres. The land is

especially well adapted for grazing purposes. In most sections there is tillable land for the production of abundant crops for winter feed or other purposes.

It is in this general area that a large percentage of the grass-finished cattle are produced, which go annually to eastern markets. The fact that most of the steers produced in this area are finished for market from grass alone attests the value of the pastures, which consist largely of blue grass. The use of grain for finishing cattle is not general, although there are many sections where the practice is followed, particularly in the valleys of the larger streams and on gently rolling areas. By far the larger number of farmers who handle beef cattle grow either stockers and feeders or finish cattle for market from grass alone. It therefore becomes one of the principal beef-production problems in this general area to determine the best and most economical method of wintering the cattle and the one that will enable them to make the best possible use of the pasture the following summer, the time when cheapest gains are made.

It has been a common practice in this area to winter steers on dry feed, such as hay, corn stover, and wheat straw, and on corn silage to a less extent, in a way that causes them to lose materially in weight. They are then pastured the following summer and sold

from grass either as stockers or feeders or as finished steers for the market. There are some who hold the idea that it is profitable to permit this loss of weight, which with older steers often amounts to from 25 to 100 pounds. There are others who believe that cattle wintered on silage, or on a ration of which silage is a part, will not do well on grass the following summer.

OBJECTS AND PLAN OF THE WORK.

The objects of the experiments as a whole had these general problems in view:

1. To ascertain the effect of different wintering rations upon subsequent pasture gains.
2. To determine the most satisfactory and economical method of wintering.
3. To determine the best method and the cost of raising beef cattle in West Virginia.



FIG. 2.—The first day on pasture, April 29, 1918, after the cattle had been wintered on a ration of corn silage, cottonseed meal, and wheat straw. (This picture shows the class of cattle, the general appearance of pasture, and the nature of the country.)

Two distinct phases of the problems as outlined in objects 1 and 2 presented themselves for solution: First, the wintering of yearlings that are to be pastured the following summer and sold as stockers or feeders; second, the wintering and subsequent grazing of older steers to be sold from grass when fat. The first, however, is the only one considered here, the second being reserved for further investigation.

The work was carried on for a period of four years, in order to have an average of feedstuffs, cattle, seasons, and other conditions tending to produce variation. The general plan of these experiments, including the rations used for the different lots of steers, is given in Table 1.

TABLE 1.—*Plan of the four years' work.*

Lot No. ¹	Season.	Steers in lot.	Winter feed. ²	Summer feed. ³
Lots 1..	1914-15	10	Corn silage, mixed hay, and wheat straw.....	Pasture.
	1915-16	10	do.....	Do.
	1916-17	10	do.....	Do.
Lots 2..	1914-15	10	Corn silage, wheat straw, and cottonseed meal.....	Do.
	1915-16	10	do.....	Do.
	1916-17	10	do.....	Do.
	1917-18	10	do.....	Do.
Lots 3..	1914-15	10	Mixed hay and wheat straw.....	Do.
	1915-16	10	do.....	Do.
	1916-17	10	do.....	Do.
	1917-18	10	do.....	Do.
Lot 4..	1917-18	10	Corn silage and soy-bean hay.....	Do.
Lot 5..	1917-18	10	Corn silage, rye hay, and cottonseed meal.....	Do.

¹ New lots of steers were used each year, totaling as follows: 1914, 30 steers; 1915, 30 steers; 1916, 30 steers; 1917, 40 steers.

² From time cattle were taken off pasture in December until turned on pasture, about May 1.

³ From time cattle went on grass in spring until sold. Each summer all the steers were turned into the same pasture and had no feed except the grass.

KIND OF STEERS USED.

The steers used in this work were of grade Shorthorn, Hereford, and Aberdeen-Angus breeding. They were raised in southern West Virginia and were a good, uniform lot of cattle in age, weight, quality, and condition. They averaged from 650 to 675 pounds in weight



FIG. 3.—Steers in Lot 1 at end of winter feeding, 1917-18.

at the beginning of the winter period and were 1 year old the previous spring.

FEEDS USED.

Samples of each of the feeds used were taken at different times throughout the four winter feeding periods and sent to the Department of Chemistry, West Virginia Experiment Station, Morgantown, W. Va., and there analyzed, with the results shown in Table 2.

TABLE 2.—Composition of feeds used.

Feeds.	Analyses (actual) as made at the West Virginia Experiment Station.				Analyses (average) as given in Henry's "Feeds and Feeding."			
	Protein.	Carbo- hydrates, includ- ing fiber.	Fat.	Ash.	Pro- tein.	Carbo- hydrates, includ- ing fiber.	Fat.	Ash.
	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
Corn silage.....	1.86	21.52	0.53	1.13	2.1	21.7	0.8	1.7
Mixed hay.....	6.60	79.49	1.90	3.74	8.6	70.7	2.4	6.1
Wheat straw.....	2.86	84.11	1.38	3.21	3.1	81.8	1.5	5.2
Rye hay.....	5.79	79.82	1.19	4.75	6.7	78.0	2.1	5.1
Soy-bean hay.....	10.00	68.90	3.02	9.08	16.0	64.0	2.8	8.6
Cottonseed meal (good).....	37.58	40.34	8.29	6.05	37.6	39.9	8.2	6.4

From the analyses it is evident that the feeds used, with the exception of cottonseed meal, were somewhat below the average in quality. The cottonseed meal used was of 41 per cent protein the first year and of 36 per cent protein the last three years. The silage was made from a mixture of dent and silage corn.



FIG. 4.—Steers in Lot 2 at end of winter feeding, 1917-18.

A three-year rotation of crops, consisting of corn, wheat, and hay, is practiced pretty generally in the section under discussion. Timothy is sown with the wheat in the fall, and clover is sown on the same field in the spring. This provides in the year following the wheat crop a mixed hay of timothy and clover. The mixed hay used in this work was obtained in this manner.

In making soy-bean hay the ground is prepared about the same as it would be for corn. The beans are drilled broadcast, using $1\frac{1}{2}$ bushels per acre. They are usually sown the last of May or the first of June, after all danger of heavy frost is past. When the beans begin to form in the pods, about the first of September, the time varying with the variety of beans and the kind of season, the crop is cut and cured for hay.

In making rye hay the seed is sown in the fall, as it would be for raising grain, except that more seed per acre is used. In the spring just before the rye blooms it is cut and cured.

The composition and nutritive ratio of the rations fed are given in Table 3.

TABLE 3.—*Dry matter, protein, carbohydrates, fat, and nutritive ratio of rations fed each year.*

Lot No.	Ration.	Average quantity per steer daily.	Composition.				Nutritive ratio.
			Dry matter.	Protein.	Carbo-hydrates.	Fat.	
1	Corn silage.....	<i>Pounds.</i> 20.0	<i>Pounds.</i> 5.26	<i>Pounds.</i> 0.220	<i>Pounds.</i> 3.000	<i>Pounds.</i> 0.140	1:14.5
	Mixed hay.....	5.0	4.39	.200	1.985	.055	
	Wheat straw.....	2.54	2.33	.018	.891	.013	
			11.98	.438	5.876	.208	
2	Corn silage.....	23.1	6.08	.254	3.465	.162	1:9.7
	Wheat straw.....	4.9	4.49	.034	1.720	.025	
	Cottonseed meal.....	1.0	.93	.334	.243	.079	
			11.50	.622	5.428	.266	
3	Mixed hay.....	11.9	10.45	.476	4.724	.131	1:12.9
	Wheat straw.....	4.07	3.73	.028	1.429	.020	
			14.18	.504	6.153	.151	
4	Corn silage.....	20.0	5.26	.220	3.000	.140	1:6.3
	Soy-bean hay.....	6.0	5.48	.702	2.352	.072	
			10.74	.922	5.352	.212	
5	Corn silage.....	20.0	5.26	.220	3.000	.140	1:10.9
	Rye hay.....	6.0	5.51	.204	2.760	.066	
	Cottonseed meal.....	.5	.46	.167	.122	.039	
			11.23	.591	5.882	.245	

From the foregoing table it is seen that the quantity of dry matter fed was practically the same in all lots, the chief difference in the ration being in the proportion of protein to carbohydrates.

CHARACTER OF PASTURE.

Each year the steers were turned on a rather rough pasture of about 160 acres, one-fourth of which is in woodland. The pasture is situated in a valley between two small mountains, and a small stream which flows through it provides an abundance of fresh water at all times throughout the summer.

The soil is of limestone formation, and a good growth of blue grass with much white clover is found on all parts of the pasture not in timber. Under normal climatic conditions there is rainfall enough to keep the grass growing throughout the season. The latter part of the summer of 1917 was rather dry, however, and during August of that year the steers made but small gains.

METHOD OF FEEDING AND HANDLING THE STEERS.

In the fall before starting the steers on the winter feed they were divided into lots of 10 each. In this division care was taken to have the lots as nearly the same as possible in regard to quality, breeding, size, and condition. These different lots were given the same amount of space in open sheds with small outside lots about 30 by 60 feet in size. Water was supplied in these lots at all times, and salt was constantly available. The cattle were fed twice a day.

The feed, both concentrates and roughages, was weighed each time and accurate records of it made. The steers were weighed at the beginning and at the end of the feeding period, the weights being taken 3 days in succession and an average taken for their initial and final weight. They were weighed also every 28 days. For identification, neck straps with numbers on them were used and individual weights taken in the morning after feeding.

I. WINTER RATIONS AND THEIR INFLUENCE ON PASTURE GAINS OF YEARLING STEERS.

QUANTITY OF FEED CONSUMED.

In considering the quantity of feed consumed it should be kept in mind that these cattle were getting only maintenance rations, but enough to keep them in good, strong, thrifty condition. Table 4 shows the total amount of different feeds eaten in the various lots and the average daily ration per steer in each lot during each of the four winters.

TABLE 4.—Average total and daily rations during four winters.

1914-15.

Lot No.	Number of steers.	Days.	Ration.	Total feed per steer.	Daily feed per steer.
				<i>Pounds.</i>	<i>Pounds.</i>
1	10	128	Corn silage.....	2,111.5	17.0
			Mixed hay.....	653.0	5.0
			Wheat straw.....	429.0	3.4
2	10	128	Corn silage.....	3,105.0	25.0
			Wheat straw.....	561.0	4.3
			Cottonseed meal.....	127.5	1.0
3	10	128	Mixed hay.....	1,278.5	10.0
			Straw.....	602.5	4.7

1915-16.

1	10	122	Corn silage.....	2,440.0	20.0
			Mixed hay.....	610.0	5.0
			Wheat straw.....	265.0	2.2
2	10	122	Corn silage.....	3,050.0	25.0
			Wheat straw.....	610.0	5.0
			Cottonseed meal.....	122.0	1.0
3	10	122	Mixed hay.....	1,464.0	12.0
			Straw.....	530.0	4.3

TABLE 4.—Average total and daily rations during four winters—Continued.

1916-17.

Lot No.	Number of steers.	Days.	Ration.	Total feed per steer.	Daily feed per steer.
				<i>Pounds.</i>	<i>Pounds.</i>
1	10	134	Corn silage.....	3,015.0	22.5
			Mixed hay.....	670.0	5.0
			Wheat straw.....	271.0	2.02
2	10	134	Corn silage.....	3,015.0	22.5
			Wheat straw.....	628.0	4.69
			Cottonseed meal.....	134.0	1.0
3	10	134	Mixed hay.....	1,622.0	12.1
			Wheat straw.....	611.0	4.56

1917-18.

2	10	133	Corn silage.....	2,660.0	20.0
			Wheat straw.....	738.0	5.55
			Cottonseed meal.....	135.0	1.0
3	10	133	Mixed hay.....	1,782.2	13.4
			Wheat straw.....	359.1	2.7
4	10	133	Silage.....	2,660.0	20.0
			Soy-bean hay.....	798.0	6.0
5	10	133	Silage.....	2,660.0	20.0
			Rye hay.....	798.0	6.0
			Cottonseed meal.....	66.5	0.5



FIG. 5.—Steers in Lot 3 at end of winter feeding, 1917-18.

GAINS AND LOSSES DURING WINTER.

The gains and losses in weight during each of the four winters are shown in Table 5.

TABLE 5.—Total and daily gains and losses during four winters.

1914-15.

Lot No.	Number of steers.	Days.	Ration.	Average initial weight per steer.	Average final weight per steer.	Total gain (+) or loss (−) per steer.	Average daily gain or loss per steer.
				<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1	10	128	Corn silage, mixed hay, and wheat straw.	622	599	−23	−0.18
2	10	128	Corn silage, wheat straw, and cottonseed meal.	618	692	+74	+ .58
3	10	128	Mixed hay and wheat straw.	623	577	−46	− .36

TABLE 5.—Total and daily gains and losses during four winters—Continued.

1915-16.							
Lot No.	Number of steers.	Days.	Ration.	Average initial weight per steer.	Average final weight per steer.	Total gain (+) or loss (—) per steer.	Average daily gain or loss per steer.
1	10	122	Corn silage, mixed hay, and wheat straw.....	Pounds. 678	Pounds. 678	Pounds. 00	Pounds. 00
2	10	122	Corn silage, wheat straw, and cottonseed meal.....	678	758	+80	+ .66
3	10	122	Mixed hay and wheat straw.....	678	671	— 7	— .06
1916-17.							
1	10	134	Corn silage, mixed hay, and wheat straw.....	690	709	+19	+ .14
2	10	134	Corn silage, wheat straw, and cottonseed meal.....	690	742	+52	+ .39
3	10	134	Mixed hay and wheat straw.....	689	659	—30	— .22
1917-18.							
2	10	133	Corn silage, wheat straw, and cottonseed meal.....	671	711	+40	+ .30
3	10	133	Mixed hay and wheat straw.....	671	615	—56	+ .421
4	10	133	Corn silage and soy-bean hay.....	671	698	+27	+ .203
5	10	133	Corn silage, rye hay, and cottonseed meal.....	671	682	+11	+ .083

Table 5 shows that in 1914-15 the cattle in Lot 1 fed on silage, mixed hay, and straw lost an average of 23 pounds in 128 days during the winter, equal to a daily loss of 0.18 pound per steer. In 1915-16 the lot fed the same ration neither lost nor gained weight during the 122 winter days. In 1916-17 the lot fed the same ration gained an average of 19 pounds, equal to a daily gain of 0.14 pound per steer.

Lot 2 in 1914-15, fed on silage, straw, and cottonseed meal, gained an average of 74 pounds in 128 days, equal to a daily gain per steer of 0.58 pound. The next year the corresponding lot gained 80



FIG. 6.—Steers in Lot 4 at end of winter feeding, 1917-18.

pounds in 122 days, making a daily gain of 0.66 pound per steer. In 1916-17 the corresponding lot gained 52 pounds per steer in 134 days, making an average daily gain of 0.39 pound. In 1917-18 the corresponding lot gained 40 pounds per steer in 133 days, making an average daily gain of 0.3 pound.

Lot 3 in 1914-15, fed on mixed hay and wheat straw with no silage, lost an average of 46 pounds, equal to a daily loss of 0.36 pound per steer. The corresponding lot in 1915-16 lost 7 pounds, equal to a daily loss of 0.06 pound per steer. In 1916-17 the corresponding lot lost 30 pounds, making an average daily loss of 0.22 pound per steer. In 1917-18 the corresponding lot lost 56 pounds, equal to a daily loss per steer of 0.42 pound.

The lot fed silage and soy-bean hay in 1917-18 gained an average of 27 pounds in 133 days, making a daily gain per steer of 0.2 pound. In 1917-18 the lot fed silage, rye hay, and cottonseed meal gained 11 pounds per steer in 133 days, or an average daily gain of 0.08 pound.

GAINS DURING SUMMER.

In the spring of each year as soon as the grass was good enough, which was usually about May 1, the steers from all the lots were turned into the same pasture on grass with no additional feed. Weights were taken every 28 days, just as during the winter. Thus the effect of the different rations upon the summer grazing of the different lots could be studied.

Table 6 shows the weights at the beginning of the grazing period, the weights at the end of the grazing period, and the total and average gains per steer for the summer period.

TABLE 6.—*Total and daily gains during four summers on pasture alone.*

1914-15.						
Lot No.	Number of steers.	Days on pasture.	Average weight per steer at beginning of grazing period.	Average final weight per steer.	Total gain per steer for summer.	Average daily gain per steer.
			Pounds.	Pounds.	Pounds.	Pounds.
1.....	10	168	599	935	336	2.0
2.....	10	.....	692	947	255	1.5
3.....	10	.....	577	892	315	1.87
1915-16.						
.....	10	167	678	1,022	344	2.1
2.....	10	.....	758	1,036	278	1.7
3.....	10	.....	671	981	310	1.9
1916-17.						
1.....	10	157	709	979	270	1.7
2.....	10	.....	742	1,000	258	1.6
3.....	10	.....	659	965	306	1.9
1917-18.						
2.....	10	140	711	969	258	1.8
3.....	10	.....	615	920	305	2.2
4.....	10	.....	698	938	240	1.7
5.....	10	.....	682	963	281	2.0

GAINS AND LOSSES, WINTER AND SUMMER.

The gains and losses in weight in both winter and summer are summarized in Table 8, and averages are shown for lots fed on the same rations in different years.



FIG. 7.—Steers in Lot 5 at end of winter feeding, 1917-18.

TABLE 7.—Summary of gains and losses in weight per steer, winter and summer.

Lot No.	Ration.	Year.	Gain (+) or loss (−) in weight per steer in winter.	Gain in weight per steer in summer.	Total gain in weight per steer, winter and summer.
1	Corn silage, mixed hay, and wheat straw.....		<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
		1914-15	−23	336	313
		1915-16	+00	344	344
		1916-17	+19	270	289
		Average.....	− 1	317	316
2	Corn silage, wheat straw, and cottonseed meal.....	1914-15	+74	255	328
		1915-16	+80	278	358
		1916-17	+52	258	3 0
		1917-18	+40	258	298
		Average.....	+62	262	324
3	Mixed hay and wheat straw.....	1914-15	−46	315	269
		1915-16	− 7	310	303
		1916-17	−30	306	276
		1917-18	−56	305	249
		Average.....	−35	309	274
4	Corn silage and soy-bean hay.....	1917-18	+27	240	267
5	Corn silage, rye hay, and cottonseed meal.....	1917-18	+11	281	292

GRAPHIC PRESENTATION OF GAINS AND LOSSES.

The comparative rapidity and extent of gains and losses can be shown more clearly by the use of a chart than in any other way. Accordingly a chart is presented herewith as figure 8, which shows the average changes in weight of the steers of the three lots.

Horizontal distance on the chart indicates the number of days that the steers were fed during the winters and pastured during the

summers. The average length of the total period for the 4 years was 288 days, of which 130 days were in the winter or feeding period and the remaining 158 in the summer or grass period. The heavy black vertical line near the center of the chart marks the dividing

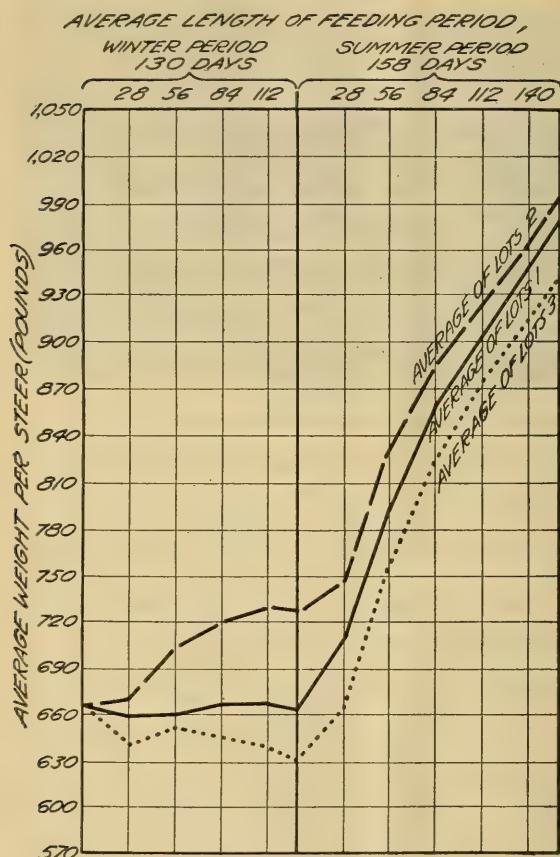


FIG. 8.—Diagram showing average variations in weights of 3 lots of steers during summer and winter feeding periods.

most of the trials a slight gain was made during this period. While the average of Lot 2 showed a small gain during the first period, it is evident that the rapidity of gain was greatly increased during the second period.

With one or two exceptions there was a marked loss in weight of steers in all lots during the last 18 days of the winter period. This falling off in weight can, no doubt, be attributed to the fact that the coming of the pasture season caused the steers to eat less dry feed and possibly to make less efficient use of what they did eat. Cattle fed on dry feed during the winter become restless with the appearance of grass and lose their appetites for the dry and less appetizing feeds which they have been receiving.

line between the winter and summer periods.

Vertical distance on the chart represents changes in live weight of the steers. The weights corresponding to each of the horizontal lines are given along the left side of the chart.

Some rather striking facts as to the way steers on different rations vary in weight from period to period during the winter are brought out. It will be noted that in Lots 1 and 3 there was an actual loss in weight each year during the first period of the winter. By the end of the second period this tendency to lose in weight had been overcome, and in

There are some very noticeable differences in the gains made by the different lots during the first 28 days of the pasture season. With one exception all lots in each trial took on weight. The steers of Lot 3 during this first period of the spring of 1917 actually lost 2 pounds per head while on grass. There is no apparent explanation for this loss, in view of the fact that both Lots 1 and 2 made gains during this same month. Since all the steers were in the same pasture and received the same treatment, no satisfactory reason for the loss by the steers of this one lot can be advanced.

As would be expected, the cattle which had been fed on a ration that caused them to lose weight during the winter made the greatest gains during this first month on pasture. The steers which had been fed on a ration of corn silage, cottonseed meal, and wheat straw and which made a steady gain throughout the winter did not make so large a gain from grass during this first period as did the steers of Lot 3, which lost weight in the winter.

The greatest gains from pasture were made by the steers of Lot 1, although the difference between this lot and Lot 3 is so slight as to be almost negligible. While the summer gains of the steers of Lot 2, fed silage, cottonseed meal, and straw, were not so large as those of the other two lots, the total of both winter and summer gains shows an increase of 49 pounds over the gain made by the steers fed mixed hay and wheat straw and 14 pounds over those fed corn silage, mixed hay, and wheat straw.

CONCLUSIONS.

1. An average daily ration of 19.8 pounds of corn silage, 5 pounds of mixed hay, and 2.5 pounds of wheat straw fed to average good steers weighing 663 pounds (Lot 1) for 130 days during the winter should maintain them without a loss in weight.

2. An average daily ration of 23.1 pounds of corn silage, 4.9 pounds of wheat straw, and 1 pound of cottonseed meal fed to average good steers weighing 664 pounds (Lot 2) for 130 days during the winter should maintain their weight and allow an average gain of 62 pounds per steer.

3. An average daily ration of 11.9 pounds of mixed hay and 4.1 pounds of wheat straw fed to average good steers weighing 665 pounds (Lot 3) for 130 days during the winter will not maintain their weight but will result in an average loss of weight of approximately 35 pounds.

4. The steers in Lot 2 receiving a protein concentrate in the ration did not lose weight as did Lots 1 and 3 (fig. 5).

5. The steers receiving corn silage as a part of their ration (Lots 1 and 2, Table 7) made greater total gains for the year than those receiving rations of dry roughage alone.

6. Steers wintered on dry roughage alone (Lot 3), which lost weight during the winter, and those fed a maintenance ration only of which corn silage was a part (Lot 1) made greater gains during the first two months on grass than those steers (Lot 2) which had made considerable gain (60 pounds) during the winter. This would be expected if the steers in the first-mentioned lots were to be finished in the same condition as those in Lot 2, as they had considerably more gain to make in order to catch up in weight.

7. There was a slight tendency for the steers fed on dry roughage alone (Lot 3) to make less gain during the last two months of the pasture season than did the steers which had received silage in the ration (Lots 1 and 2) during the preceding winter, although this difference was very slight.

II. THE USE OF SILAGE AND THE COST OF RATIONS FOR WINTERING YEARLING STEERS.

Shall I purchase steers (that are to be fattened from grass the next summer) in the fall, and carry them through the winter largely on roughage, or shall I purchase them in the spring after some one else has wintered them? This is a question which the thoughtful cattle grazer in the good pasture areas is likely to ask himself and which it is of considerable importance to answer correctly. No matter what the answer may be on any particular farm or in any particular section of country, the fact remains that cattle are higher in price and are worth more in the spring just before the grass season opens than they were at the close of the pasture period the preceding fall. This increase in value is due largely to the cost of wintering, depending upon the rations and methods used.

The data already presented in this bulletin afford an opportunity to throw some light upon this important subject. In the following discussion of this question it is necessary to fix the prices for feeds on the farm. It is felt, however, that this is the most questionable and unsatisfactory part of such experimental work, and is especially true for the last few years, during which unusual fluctuations have occurred in feed prices.

PRICES OF FEEDS USED.

During the four years that this experiment was in progress the price of silage increased from \$4 to \$8 a ton, cottonseed meal from \$30 to \$60, and hay and straw advanced respectively 33½ and 50 per cent. Thus the cost of wintering a steer in 1917-18 was nearly double the cost of keeping him through the winter 1914-15. While feed prices remain high, it is not certain that they will continue at the present high level for any great length of time. For this reason, and also for simplicity in making the various calculations, an average of the feed prices for the four years is used, as follows:

	Per ton.
Corn silage.....	\$6
Mixed hay.....	18
Rye hay.....	18
Soy-bean hay.....	17
Wheat straw.....	7
Cottonseed meal.....	50

The foregoing averages were made from figures taken from the Yearbook of the United States Department of Agriculture, and are the average farm prices in the States of West Virginia, Virginia, Maryland, Pennsylvania, Ohio, Kentucky, Tennessee, North Carolina, and parts of other adjacent States, to which this work is most applicable.

An attempt is made to show the comparative cost of the different rations for the benefit of those who desire information on this phase of the subject. If the prices of feeds in any locality are different from the prices used in these calculations, it is suggested that they be substituted and the following calculations used as a guide, using, as the basis of calculation, the total amounts of the different feeds consumed per steer as shown in the first section of Table 4.

Table 8 shows the rations fed, the gain or loss in weight per steer during the winter, the fall cost per hundredweight, the cost of feeding each steer through the winter, and the advance in spring value over fall cost of steers per hundredweight.

TABLE 8.—Summary of rations, costs, and results.

Lot No.	Ration.	Year.	Gain(+) or loss (−) in weight per steer.	Initial value per hundred-weight.	Cost to winter each steer.	Value in spring per hundred-weight.	Advance in spring value over initial value per hundred-weight.
			<i>Pounds.</i>				
1	Corn silage, mixed hay, and wheat straw.	1914-15	−23	\$6.50	\$13.71	\$9.04	\$2.54
		1915-16	00	6.50	13.74	8.52	2.02
		1916-17	+19	7.00	16.03	9.07	2.07
		Average.....	− 1	6.67	14.49	8.88	2.2
	Corn silage, wheat straw, and cottonseed meal.	1914-15	+74	6.50	14.47	7.89	1.39
2		1915-16	+80	6.50	14.34	7.70	1.20
		1916-17	+52	7.00	14.60	8.48	1.48
		1917-18	+40	7.50	13.88	9.03	1.53
		Average.....	+62	6.88	14.32	8.28	1.40
	Mixed hay and wheat straw.....	1914-15	−46	6.50	13.62	9.38	2.88
3		1915-16	− 7	6.50	15.03	8.81	2.31
		1916-17	−30	7.00	16.74	9.72	2.72
		1917-18	−56	7.50	17.30	11.00	3.50
		Average.....	−35	6.88	15.67	9.73	2.85
	Corn silage and soy-bean hay.....	1917-18	+27	7.50	14.76	9.32	1.82
4							
5	Corn silage, rye hay, and cottonseed meal.	1917-18	+11	7.50	16.82	9.84	2.34

NOTE.—The length of the feeding period varied somewhat from year to year, depending on the condition of the pastures in the early spring. The steers were fed 128 days during the winter of 1914-15, 122 days in 1915-16, 134 days in 1916-17, and 133 days in 1917-18.

COST PER POUND OF GAIN.

The cost of producing a pound of gain is the main factor in determining whether a steer is being produced at a profit or a loss. The cost of feeding a steer during the winter, plus the cost of pasture the following summer, is the total cost of feeding the steer for the year. By dividing this amount by the increase in weight of the steer, the cost of producing a pound of gain may be ascertained. From Table 8 it will be noted that the winter cost constitutes approximately two-thirds of the total cost for the year. Practically all the gain, however, is made during the summer or pasture season. Hence the cost of wintering becomes the governing factor in determining the cost of a pound of gain. A summary of gains and costs is given in Table 9.

TABLE 9.—*Summary of gains and costs.*

Lots No.	Ration.	Year.	Total gain, winter and summer, per steer.	Cost per steer, winter.	Cost per steer, summer. ¹	Total cost of feed and pasture per year per steer.	Cost per pound yearly gain.
			<i>Pounds.</i>				
1	Corn silage, mixed hay, and wheat straw.	1914-15	313	\$13.71	\$8.40	\$22.11	\$0.070
		1915-16	344	13.74	8.35	22.09	.064
		1916-17	289	16.03	7.85	23.88	.083
		Average.....	316	14.49	8.20	22.69	.072
2	Corn silage, wheat straw, and cottonseed meal.	1914-15	328	14.47	8.40	22.87	.070
		1915-16	358	14.34	8.35	22.69	.063
		1916-17	310	14.60	7.85	22.45	.072
		1917-18	298	13.88	7.00	20.88	.070
		Average.....	324	14.32	7.90	22.22	.069
3	Mixed hay and wheat straw.....	1914-15	269	13.62	8.40	22.02	.082
		1915-16	303	15.03	8.35	23.38	.077
		1916-17	276	16.74	7.85	24.59	.089
		1917-18	249	17.30	7.00	24.30	.097
		Average.....	274	15.67	7.90	23.57	.086
4	Corn silage and soy-bean hay.....	1917-18	267	14.76	7.00	21.76	.081
5	Corn silage, rye hay, and cottonseed meal.	1917-18	292	16.82	7.00	23.82	.081

¹ The cost of summer feed is calculated at the same rate for each lot each year, charging the pasture at 5 cents a day, as follows:

168 days, 1915.....	\$8.40
167 days, 1916.....	8.35
157 days, 1917.....	7.85
140 days, 1918.....	7.00

The steers of Lots 2, which were fed corn silage, wheat straw, and cottonseed meal, made the greatest gains during the year at least cost for feed. Hence the cost of a pound of gain was lowest for these lots, the average for four years being 6.9 cents.

Lots 1, fed corn silage, mixed hay, and wheat straw, put on gains at an average cost of 7.2 cents a pound.

Steers fed mixed hay and wheat straw, which is by far the most commonly used ration in the section under discussion, made smaller yearly gains at greater cost than did the steers of the two lots aforementioned. It cost 8.6 cents to put on a pound of gain when the wintering ration consisted of mixed hay and wheat straw.

The cost of producing a pound of gain was comparatively high in Lots 4 and 5, being 8.1 cents a pound for each lot. The rations used, while an improvement over the commonly used combinations of mixed hay and wheat straw, were too costly, when resulting gains are considered, to be recommended except when mixed hay is not available.

VALUE OF GAINS.

In Table 10 the increase in value per steer is shown. The initial cost plus the cost of feed and pasture is the total cost of the steer at the close of the pasture season. The appraised valuation of the steers at this time was \$2 per hundredweight more than the initial cost per hundredweight the preceding fall. While this is an arbitrary valuation, nevertheless it represents a very conservative figure, the actual increase in most instances being much more.

The cost of labor and other cost factors are not considered; such items would be more than offset by the value of the manure from the cattle.

TABLE 10.—*Summary of costs showing increased value of steers at end of winter feeding period.*

Lots No.	Year.	Initial value per steer.	Cost to feed each steer one year.	Value of steer, including cost of feed and pasture.	Appraised value of steer at end of year.	Increase over initial value plus cost of feed and pasture.
1	1914-15.....	\$40.43	\$22.11	\$62.54	\$79.48	\$16.94
	1915-16.....	44.07	22.09	66.16	86.87	20.71
	1916-17.....	48.30	23.88	72.18	88.11	15.93
	Average.....	44.27	22.69	66.96	84.82	17.86
2	1914-15.....	40.17	22.87	63.04	80.50	17.46
	1915-16.....	44.07	22.69	66.76	88.06	21.30
	1916-17.....	48.30	22.45	70.75	90.00	19.25
	1917-18.....	50.33	20.88	71.21	92.06	20.85
	Average.....	45.72	22.22	67.94	87.66	19.72
3	1914-15.....	40.50	22.02	62.52	75.82	13.30
	1915-16.....	44.07	23.38	67.45	83.39	15.94
	1916-17.....	48.30	24.59	72.89	86.85	13.96
	1917-18.....	50.33	24.30	74.63	89.11	14.48
	Average.....	45.80	23.57	69.37	83.79	14.42
4	1917-18.....	50.33	21.76	72.09	91.49	19.40
5	1917-18.....	50.33	23.82	74.15	87.40	13.25

The estimated value per hundredweight at the end of the pasture season of all lots was the same, regardless of the extra finish due to

greater gains made by the silage-fed lots. Steers from all lots were to be carried over and finished the following year; hence, no actual selling price is given. Had these increased gains been taken into consideration in estimating the value, the added profit per steer for the lots fed silage and cottonseed meal would have been even greater than the amounts shown in Table 10. In this table, as in all others, the steers of Lot 2, fed corn silage, wheat straw, and cottonseed meal, appear to best advantage, for they returned a profit of \$19.72 per steer as compared with \$17.86 for Lot 1 and \$14.42 for Lot 3. Lots 4 and 5 were included in the table, but in the comparisons and conclusions drawn they are not considered, as they were carried only one year.

VALUE OF SILAGE IN THE RATIONS.

In Table 11 the added value per steer to be gained by the use of corn silage and also of cottonseed meal in the rations is shown. Since most of the cattle wintered in West Virginia and neighboring States are carried through on dry feed, the steers fed mixed hay and wheat straw were used as a basis from which to make comparisons and those feeds were considered a check ration.

The increased value of the steer in the spring over the fall value depends very largely upon the method of wintering, as is shown in Table 8, being from \$1.40 to \$2.85 per hundredweight. When the better methods are used the increase based upon the cost of wintering will be on the average about \$2 per hundredweight, which is the figure used in making these calculations.

TABLE 11.—*Summary showing value of silage rations as compared with hay and straw (check ration).*

Ration.	Average yearly gain per steer.	Increased gain per steer over steers fed check ration.	Value of increase in gain per steer.	Average yearly cost of feed and pasture per steer.	Decrease in cost of ration as compared with check ration.	Increased value of ration per steer as compared with check ration.
	<i>Pounds.</i>	<i>Pounds.</i>				
Mixed hay and wheat straw (check ration)	274			\$23.57		
Corn silage, mixed hay, and wheat straw...	316	42	\$3.73	22.69	\$0.88	\$4.61
Corn silage and soy-bean hay.....	267	7	¹ —.62	21.76	1.81	1.19
Corn silage, rye hay, and cottonseed meal...	292	18	1.60	23.82	² —.25	1.35
Corn silage, wheat straw, and cottonseed meal.....	324	50	4.44	22.22	1.35	5.79

¹ Decrease.

² Increase.

The addition of corn silage to the dry-feed ration resulted in an increase of 42 pounds in the yearly gain of each steer as compared with the check ration, and the substitution of cottonseed meal and corn silage in place of mixed hay produced an increase of 50 pounds of gain per steer. At the estimated value—\$2 margin above the initial cost per hundredweight—these additional gains would be

worth \$3.73 and \$4.44, respectively. If the three rations had cost the same per steer per year, these figures would represent the added profit. With feeds at prices as charged during the first three years, however, the dry-feed ration was the most costly. It cost 88 cents less to feed a steer on corn silage, mixed hay, and wheat straw than on mixed hay and straw alone. The addition of cottonseed meal and the elimination of the hay decreased the cost \$1.35. By adding these figures to the value of the increased gains, the total added profit per steer can be obtained. In the case of the steers fed corn silage, mixed hay, and wheat straw, this amounted to \$4.61, and for the steers fed on corn silage, cottonseed meal, and straw the corresponding figure was \$5.79.

Since the average initial weights of the lots were practically the same for each trial, and since all lots were summered on the same pasture, the difference in final weight can be attributed to the different rations fed during the winter.

GENERAL SUMMARY OF COSTS AND GAINS.

A general summary of costs and gains is given in Table 12.

TABLE 12.—*General summary of costs and gains.*

Items.	Lots 1, (corn silage, mixed hay, and wheat straw).	Lots 2, (corn silage, wheat straw, and cotton- seed meal).	Lots 3, (mixed hay and wheat straw).	Lots 4, (corn silage and soy- bean hay).	Lots 5, (corn silage, rye hay, and cot- tonseed meal).
Average cost of wintering.....	\$14.49	\$14.32	\$15.67	\$14.76	\$16.82
Average length of winter periods..... days..	128	129½	129½	133	133
Cost of feed per day, winter.....	\$0.116	\$0.111	\$0.121	\$0.111	\$0.127
Average cost of summer feed.....	\$8.20	\$7.90	\$7.90	\$7.00	\$7.00
Average length of summer periods..... days..	164	158	158	140	140
Cost per day, summer.....	\$0.05	\$0.05	\$0.05	\$0.05	\$0.05
Average of total costs per year.....	\$22.69	\$22.22	\$23.57	\$21.76	\$23.82
Average gain or loss per steer, winter..... pounds..	-1	+62	-35	+27	+11
Average gain per steer, summer..... do.	317	262	309	240	281
Average total gain per steer..... do.	316	324	274	267	292
Cost per pound yearly gain.....	\$0.072	\$0.069	\$0.086	\$0.081	\$0.081

CONCLUSIONS.

1. Corn silage, wheat straw, and cottonseed meal (fed to Lots 2) was the cheapest ration used and at the same time the best, making the greatest increase (62 pounds) in weight of the steers. It is seldom that one gets the best for the least money.

2. Silage added to a ration for wintering steers makes it more economical than dry roughage alone, considering the gains made both during the winter and in the summer following the winter feeding period.

3. With but few exceptions, a farmer or stockman (in the section considered) who has a sufficient number of mature cattle or their equivalent is justified in building a silo.

4. After the farmer or stockman has his silo he may advantageously buy a protein supplement. The quantity of cottonseed meal or other protein-rich feed would perhaps be regulated by the kind of roughage used with the silage. If a legume hay were used, the cottonseed meal or other protein concentrate could be eliminated entirely or at least reduced very materially in quantity.

5. The addition of corn silage to the ration for wintering yearling steers gave them an increased value of from \$1.19 to \$5.79 per head, depending upon the ration used.

6. As a general rule, where the farmer has silage and a roughage in the form of straw or various kinds of hay and stover, it would seem advisable to feed his yearling cattle (should he wish to winter them and sell them from grass the next summer) a ration of silage, a little cottonseed meal—not more than 1 to 1½ pounds—or other such feed, and the roughage that he has available.

7. The cost of wintering a yearling steer is approximately two-thirds the cost of keeping the steer one year. The profit, therefore, may be largely determined from the ration used and method of wintering.

8. The feeding methods used in wintering yearling steers added from \$1.40 to \$2.85 per hundredweight to the spring value over the value the preceding fall, depending upon the ration used.

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PROFESSIONAL PAPER

November 10, 1920

THE DRY-ROT OF INCENSE CEDAR.

By J. S. BOYCE, *Assistant Pathologist, Office of Investigations in Forest Pathology.*

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IMPORTANCE OF INCENSE CEDAR.

Incense cedar (*Libocedrus decurrens*) is of considerable economic importance on the Pacific coast. The available supply of this species, which never occurs alone but always in mixture, chiefly with yellow pine, Jeffrey pine, sugar pine, Douglas fir, and white fir, averaging about 8 per cent of the stand, although often forming as high as 30 to 50 per cent, is estimated at 11 billion feet, 10 billion of which occurs in California (17, pp. 9-10).¹ That the wood is very valuable for special purposes on account of certain qualities has been clearly pointed out by Mitchell (17, pp. 2-9) recently and was mentioned by Von Schrenk (26, p. 69) 20 years ago. However, in spite of the well-known value of the wood, only about 30 million feet is cut annually in California. The stumpage rate is low and the price for the finished product often little more than pays the cost of logging and manufacture, according to Mitchell (17, p. 6).

The reason for this is obvious. The heartwood of incense cedar is commonly rendered totally worthless by the so-called dry-rot caused by *Polyporus amarus*. An idea of the quantity of timber rendered unmerchantable by this dry-rot may be obtained from Mitchell's statement (17, p. 3) that so common is this defect that it is the usual practice to cut estimates of this species from 30 to 50 per cent on ac-

¹ The serial numbers in parentheses refer to "Literature cited" at the end of the bulletin.

count of it. This leads to a distinct prejudice against the species on the part of both the lumberman and the forester. The lumberman is naturally averse to handling a large quantity of practically worthless material for which there is little or no market in order to secure a small amount of valuable material, when the profit on the more valuable product is not sufficient to carry adequately the entire product. The forester sees a species of very little value, as attested by the low stumpage rate, occupying space which might be given over to surrounding species on which a much higher stumpage rate could be realized.

This prejudice, which has resulted in the classification of incense cedar as an "inferior" species, is not based on any inherent quality of the tree itself, for sound cedar wood, as has already been stated, is quite valuable, finding a ready market; and the tree, on account of its relatively high tolerance of shade, particularly during its earlier life, is a valuable component of the mixed stand in which it occurs.

Incense cedar is a thrifty, aggressive species, quite tolerant of shade, and has a definite, permanent place in the forests of the Pacific coast. Its aggressiveness makes it almost an impossibility to eradicate the species entirely, and such an attempt would be highly inadvisable and might result in unforeseen disastrous consequences resulting from an artificial change in the composition of the stand. Greeley (6, p. 112) and Meinecke (16, pp. 21-22) have specifically advised against this. The lumberman, logging in types with incense cedar represented, faces the necessity of handling a large quantity of almost worthless timber, which if sound would be of high value.

Since incense cedar probably can not be eliminated from the stand, the problem presents itself of the proper treatment of an inferior species which in time will undoubtedly become quite valuable. Foresters and lumbermen are showing more and more interest in the question, fully realizing that this species will always have to be reckoned with. We must have exact, far-reaching studies not only to handle properly and utilize the cedar at present, but to lay the foundations for a rational system of silvicultural management for the future. Production is inevitable; proper treatment must be evolved. Consequently, the study on which this paper is based was undertaken in an attempt to throw light on certain of the phases involved.

TOTAL-LOSS FACTORS.

Throughout American forestry literature dealing with regulation and management are found statements in regard to individual components of mixed stands to the effect that "in virgin forests increment equals decay," or sometimes "deterioration" is used in place of "decay." Chapman (2, p. 317) and Meinecke (16, p. 3-4) have shown this generalization to be of absolutely no value, since the as-

sumption is based on the factors of increment and decay, of which almost nothing is known. When deterioration is used in place of decay, it is an impossibility to reach a conclusion as to just what factors of loss are included in the term.

The term "total loss" has been introduced by Meinecke (16, p. 4-5) to cover all factors which lead to any reduction of increment or actual volume in a stand, and he makes a strong plea for exact studies of all components of the total-loss factor for individual species before any effort is made to determine this for the mixed stand.

To determine the components of the total-loss factor for any given species is merely a matter of simple observation, but to gauge accurately their relative importance is not easy, calling for careful comprehensive work.

In the case of incense cedar the numerical dropping out of individual trees, the mechanical injuries caused by fire, frost, lightning, the breaking of branches, and other causes, a mistletoe, and several fungi play a more or less important part in the total-loss factor. These components may be divided into two broad classes, those reducing the future capital of timber (lessening the increment) and those reducing the present capital of timber (destroying actual merchantable material). It is impossible to draw a sharp line between these two classes, since some components find a place in both.

The unavoidable yearly dropping out of certain trees, varying in size from seedlings to veterans, affects both the increment and merchantable material in a stand. Mechanical injuries, while primarily causing a loss in the merchantable timber, to some extent interfere with the normal growth of the tree, thus reducing the increment.

A mistletoe (*Phoradendron juniperinum libocedri*), the incense-cedar rust (*Gymnosporangium blasdaleanum*) (15, p. 35-37; 11), a leaf-inhabiting fungus (*Stigmatea sequoiae*) (3, p. 87; 4, p. 314), and the black cobweb fungus (*Herpotrichia nigra*) all primarily cause a loss in the future capital of timber by reducing the annual increment of infected trees. The amount of this loss is exceedingly difficult to gauge accurately, but it is so small in relation to the damage caused by the agencies reducing the present capital of timber that the above-mentioned organisms are given no consideration in this paper except incidental mention. Under certain conditions, the mistletoe is responsible for a slight reduction in the merchantable contents of the host tree by causing spindle to barrel shaped swellings on the boles of mature and overmature trees (14, p. 37). The wood of these swellings is rendered valueless for lumber, owing to the presence of the mistletoe "sinkers," or roots, either living or dead. Swellings are rarely, if ever, found on the boles of younger trees.

Most important of all, however, is the loss of the present capital of timber through decay. The organisms causing decay in incense cedar are the pouch fungus (*Polyporus volvatus*), *Polystictus abietinus*, *Polystictus versicolor*, *Lenzites sepiaria*, the red-belt Fomes (*Fomes pinicola*), some unknown fungi, and the incense-cedar dry-rot fungus (*Polyporus amarus*). The first five listed have never been found attacking living incense cedars. There are several forms of decay of trifling importance in living trees, the causes of which have not been determined. *Polyporus schweinitzii* has been found in one case.

Standing out above all the other components of the total-loss factor is *Polyporus amarus*, causing dry-rot in the heartwood of the tree. Since the first utilization of incense cedar, the great destruction wrought by this fungus has been a matter of extreme concern to lumbermen and foresters, as is shown by the constant references to the decay found throughout the literature wherever incense cedar is mentioned.

The importance of dry-rot can not be overestimated, and it is on this point, together with the related mechanical injuries, that a study of the total-loss factor must be concentrated; the other considerations play a distinctly secondary rôle.

METHOD OF COLLECTING DATA.

SELECTION OF AREAS.

The first step in carrying on a study of the total-loss factors in any given species is the selection of proper areas for work. The areas selected, if the results are to serve for any but strictly local application, must be representative of the larger unit or region of which they form a part. It is self-evident then that areas located in the altitudinal or horizontal extremes of the range of the species under investigation must be avoided. The results of a study on such areas, while scientifically interesting, would be absolutely without practical value, since they would only answer for a limited unit on which the stand is abnormal and would fail to answer any questions in regard to the major and more valuable portion of the range of the species.

All indications tend to show that there is a considerable variation in the growth and development of incense cedar in different parts of its range. This has already been hinted at by Mitchell (17, p. 9, 13, 23, 24). The writer distinguishes three distinct ranges based on the development of the tree, and these are termed, for convenience, the optimum, intermediate, and extreme ranges.

The best development is found in the southern Sierras, particularly on the Sierra, Sequoia, and Stanislaus National Forests, and the southern portion of the Eldorado National Forest, where the species is relatively rapid growing and thrifty.

In the intermediate range, comprising the northern Sierras and the Coast Ranges, slower growth is the rule, and in the mixed stand where the cedar always occurs it plays a distinctly secondary part and might almost be classed as an understory tree.

The poorest development is found in the extreme range, which includes stands at the horizontal and altitudinal extremes of the distribution of the species. In such situations the trees are short, scrubby, and relatively of little value.

With the above facts in mind, it was considered essential to choose areas representative of the intermediate and optimum range; the extreme range could be neglected, since it is of no practical importance.

In the uneven-aged stands care had to be observed to select areas on which all age classes were represented, since if there is a relation between any of the total-loss factors and age of the tree, this would fail to appear if even-aged or nearly even-aged trees alone were considered.

Observation and a preliminary study by Meinecke¹ showed conclusively that the total-loss factor of supreme importance in the case of incense cedar is dry-rot caused by *Polyporus amarus*. Above all, then, it was essential to select stands in which dry-rot was common, using discretion not to make the selections where loss from dry-rot was far above or below normal. Other total-loss factors, particularly mechanical injuries, could not be disregarded and were carefully considered.

With a knowledge of the habits and condition of incense cedar throughout its range, several possible areas were tentatively chosen, a careful examination made in each case, and then the most suitable stands were decided upon.

DESCRIPTION OF AREAS.

The area selected to represent the intermediate range is at Sloat, Calif., within the boundaries of the Plumas National Forest, in the northern Sierra Nevada Mountains. In general, the region is one of heavy snowfall, with moderate winter temperatures and a long, dry, warm summer season. Lightning storms are not very frequent.

The tract has a relative altitude of 4,300 to 4,700 feet. The fairly deep soil is a decomposed lava, normally dry and loose.

The virgin uneven-aged stand, with a strong representation of mature and badly overmature trees of all species, is principally composed of western yellow pine (*Pinus ponderosa*), Jeffrey pine (*Pinus jeffreyi*), and Douglas fir (*Pseudotsuga taxifolia*). Where

¹The writer wishes to acknowledge his indebtedness to Dr. E. P. Meinecke, who first inaugurated a study of incense cedar in 1912, the data obtained being included in this paper, for advice and direction throughout the course of all the later work. The essential methods followed in this study are outlined by him in United States Department of Agriculture Bulletin 275 (16).

Douglas fir predominates, the two pines take second place, and vice versa. Third in order comes incense cedar, while sugar pine (*Pinus lambertiana*) and white fir (*Abies concolor*) are but lightly represented.

In the more dense stand on the lower slopes and in the draws incense cedar forms a distinct understory, overtopped by all the other species; it is in such localities that the cedar shows every indication of slow growth and strong suppression. On the higher slopes and along the ridges, where the stand is more open, the cedar in individual cases often assumes a better position in the stand, and all the trees of this species, with few exceptions, appear to be more thrifty and to have made a more rapid growth. Badly suppressed trees are rare.

The three areas selected to represent the optimum range are on the Stanislaus National Forest in the southern Sierra Nevada Mountains. One of these is at Strawberry, at an altitude of 5,300 to 5,600 feet; a second at Cow Creek, about 5 miles north and east of the first and at about the same elevation; and the third at Crockers Station, about 30 miles to the south and a little east of the Strawberry area and at an altitude of about 4,500 feet. Since the areas are so nearly alike, a composite description will suffice.

The soil is a rather deep, loose, decomposed granite, with many large granite boulders. It is normally somewhat dry.

The virgin uneven-aged overmature stand is rather open and is composed of sugar pine, western yellow pine, Jeffrey pine, white fir, incense cedar, and Douglas fir. Normally the pines predominate, with white fir or incense cedar next in order, Douglas fir being found sparingly only on the Crocker area. Incense cedar is represented by trees of all ages, and on the whole appears very thrifty. There are many individuals of large size, comparatively young. The cedar here is far from forming such a distinct understory as on the Sloat area, so the stand has made a much more rapid growth.

NOTES ON INDIVIDUAL TREES.

After the general notes were completed on an area, work was commenced on individual trees. Trees of all ages and conditions must be cut for a study of this kind, the primary purpose being to determine the age of the stand at which dry-rot becomes extensive. Observations on logging operations and the results of Meinecke's preliminary study had shown that trees between 100 and 240 years old would yield the essential data on this point, and it was within these age limits that the investigation was concentrated, but the lower and higher ages were not neglected by any means. This resulted in clear cutting within the ages mentioned, except that those trees in which it was plainly apparent an accurate age count could not be made were left standing, while only a portion of the trees in the stand above and below these ages were cut. Thus, since a given

tract was not clear cut, the representation of age, diameter breast high, and height classes obtained from the study must not be assumed as an exact expression of the actual conditions.

Each tree was cut as closely as possible to a stump height of 18 inches, then limbed and bucked. The first or butt log was made 7 feet long and the others 14 feet long, the number of cuts depending, of course, on the length of the tree. The last cut was always made well in the top near the upper limit of the heartwood. The reason for bucking in 7 and 14 foot lengths was purely a practical one; any sound heartwood could then be utilized for 7-foot posts. The age count at stump height was taken as the age of the tree instead of adding a few years corresponding to the height of the stump, since the aim is to have all figures taken directly comparable. In this case with a minute constant variation no error can be introduced. Trees with wounds which destroy the center at stump height were avoided when possible, since in such cases an accurate age count could not be obtained; hence, trees of this kind are valueless for all further calculations in which the exact age is a factor. The sap width was obtained from an average of six or eight measurements. Three radii were measured to secure the average diameter. Separate measurements were made for the area covered by decay. The dates of occurrence and closure, when healed, were determined for all wounds present. Each log was split at least once in order to reveal completely all decay and internal wounds. Great care had to be observed in splitting the logs in order to be certain not to miss any decay, since the dry-rot occurs in pockets which may be separated in a linear direction by several feet of sound wood. This habit of "jumping" also made it exceedingly difficult to trace the entrance of the decay in certain cases where the decay might be several feet removed from any possible point of entrance. It often became necessary to split log after log into many small pieces.

In all, 1,075 trees were analyzed, 509 at Sloat, 266 at Strawberry, 100 at Cow Creek, and 200 at Crockers Station.

In all future references in this paper, for the sake of convenience the term "intermediate area" will be used to designate the area at Sloat, since it represents conditions in the intermediate range, and the term "optimum area" to designate the combined areas at Strawberry, Cow Creek, and Crockers Station, since they represent conditions in the optimum range. The results of the field work follow.

SECONDARY ROTS.

Under this heading are grouped all decays the causes of which are unknown. Such decays are of various types and are almost invariably found immediately adjacent to open or healed-over wounds, particularly fire scars. Instances were encountered where

the decays were so badly eaten out by insects as to preclude any description of the rot. By reason of this, some light infections of *Polyporus amarus* may have been included under secondary rots, but such cases have undoubtedly been very rare.

Of the 59 infections of secondary rots examined, only 9 resulted in culls of any importance, the highest percentage of unmerchantable timber in relation to the total volume of the tree being 19.5 per cent. In all the remaining 50 trees the infections were negligible. These figures show secondary rots to be of only trivial importance in reducing the merchantable volume; hence, such decays are not further considered in this paper.

THE DRY-ROT.

The dry-rot of incense cedar, termed by eastern workers "peckiness" or "pin-rot," caused by the fungus *Polyporus amarus* Hedge., was first described and figured by Harkness (7) but no cause was given. Next Von Schrenk (26, 67-77, pl. 2, 4, 5) described and figured the disease without stating the cause, and later (28) he mentions *Polyporus libocedris*, but without giving a description of type specimens. Hedgcock (10) first definitely assigned the cause of the dry-rot to *Polyporus amarus* sp. nov. and described the fungus. Later Meinecke (15, p. 35-37) presented a brief description of the sporophore, accompanied by a photograph of a typical fully developed bell-shaped specimen, with the upper surface partially destroyed by insects. Murrill (24, p. 25) places the fungus in the genus *Fomes*.

Harkness and Moore, Mayr, and Sargent have attributed the cause of the dry-rot to *Daedalea vorax* Hke., but Von Schrenk (26, p. 67-68) has shown this to be an error. Farlow and Seymour (5, p. 169) and Bryant (1, p. 15) have made the same mistake.

The dry-rot is very widely distributed. It has been found at elevations varying from 650 to 6,480 feet as far north as Oakridge, Lane County, Oreg., west to the west of China Flat, Humboldt County, Calif., east to Shaver, Fresno County, Calif., and south to the north and east of Mentone, San Bernardino County, Calif. In fact, from all indications and hearsay evidence it is quite reasonable to presume that dry-rot is more or less prevalent in incense cedar throughout the range of the host (30, p. 150-152).

THE SPOROPHORE.

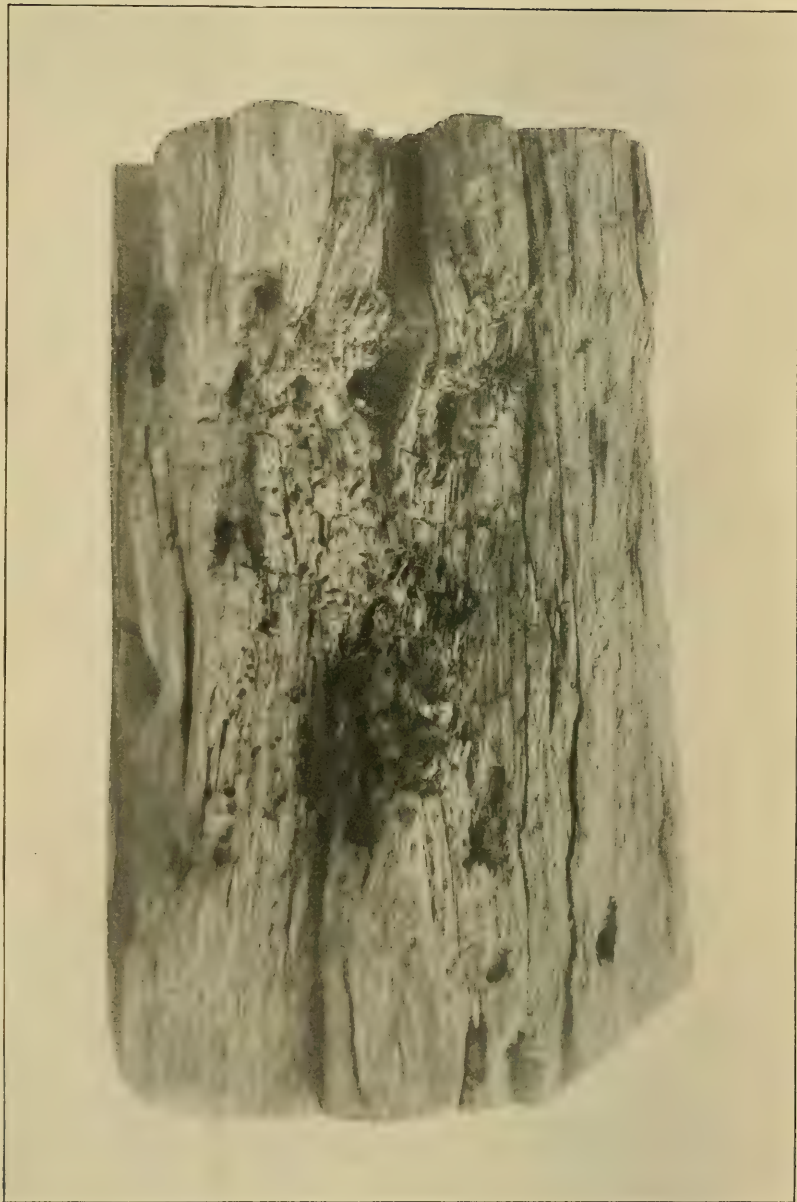
Since Hedgcock's description was published, so many sporophores have been collected that the original description may be supplemented by the following, which is based on the examination of 25 sporophores, both fresh and old:

Polyporus amarus.—Pileus soft and mushy when young, then rather tough and cheesy, finally becoming hard and chalky when old, unguulate, bell shaped or occa-



A FRESH SPOROPHORE OF POLYPORUS AMARUS ON A DOWN TREE.

Photographed by Gravatt.



AN OLD SHOT-HOLE CUP. THE ORIGINAL SPOROPHORE ISSUED FROM THE KNOT HOLE AT THE TOP.

Photographed by Meinecke.

sionally subapplanate, often spuriously stipitate from knot holes, 4 to 15 by 5 to 22 by 5 to 20 cm., commonly 7 to 10 by 11 to 13 by 8 to 13 cm., occasionally abortive without hymenial layer, then assuming irregular shapes; surface pubescent when young, rimose and chalky when old, at first buff, then tan, and often blotched with brown when attacked by insects; margin obtuse, frequently having an outer band of darker brown, often slightly furrowed; context homogeneous,¹ lemon-yellow, later buff to tan, usually darker near the surface when old, slightly bitter to the taste, 4 to 14 cm. thick, commonly 9 to 11 cm., usually friable when dry but occasionally becoming partially horny, hard; tubes not stratified, lemon-yellow within, cylindric 0.2 to 3 cm. in length, shorter next the margin, mouths circular or slightly irregular, 1 to 3 to a millimeter, lemon or sulphur yellow during growth, turning brown when bruised or old, becoming lacerate; under surface of the hymenial layer sometimes exuding clear yellow drops of liquid, sweetish to taste; spores hyaline or slightly tinged with yellowish brown, smooth, ovoid (200) range 3 to 6.5 μ by 4.5 to 9 μ ; standard size 3.5 to 4.5 μ by 6.5 to 7 μ , nucleated; cystidia none.

The following table presents detailed measurements of 24 sporophores of *Polyporus amarus*:

TABLE I.—*Sporophore measurements of the incense-cedar dry-rot fungus.*

cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
3.8 by	4.8 by	8.3	8.0 by	13.0 by	13.0	9.5 by	17.0 by	13.3	
4.2 by	5.5 by	5.5	9.0 by	11.5 by	9.9	9.8 by	13.2 by	13.0	
6.0 by	7.3 by	8.6	9.0 by	10.0 by	10.0	10.3 by	14.9 by	14.8	
6.8 by	11.2 by	12.3	9.0 by	10.5 by	11.0	11.4 by	20.7 by	19.8	
7.5 by	11.4 by	9.0	9.0 by	13.3 by	12.0	12.0 by	16.4 by	10.8	
7.5 by	17.0 by	8.1	9.1 by	10.7 by	8.5	12.1 by	21.2 by	12.5	
7.6 by	11.4 by	9.5	9.1 by	12.4 by	8.9	14.5 by	22.0 by	13.0	
8.0 by	12.5 by	10.0	9.5 by	14.7 by	11.0	14.8 by	12.7 by	16.5	

The sporophores, which last for one season only even at best, are not at all common, a statement which is supported by the number of years the dry-rot was known before the cause was definitely determined. During certain years sporophores seem to be very rare. They most commonly occur in the summer, and especially in the fall, but occasionally are found at other seasons. Observations record two fresh ones in March in a rather mild climate at an altitude of about 3,000 feet in the Sierra Nevada. Another was found in a different locality in June. No sporophores have been found developing later than October, but occasional fresh ones may be carried over from a previous fall into the winter in a frozen condition. They are then destroyed in the spring.

Typically the sporophores are produced on living trees but are, on occasions, found on dead fallen trees. (Pl. I.) Seven such cases have been observed during the past five years. In five of these it was possible to determine the time which elapsed between the felling of the tree and the appearance of the sporophore. Three of the sporophores were produced 3 years, one 4 years, and one 27 years after the trees had been cut. As to how long the mycelium may

¹ The substance of the sporophore not including the outer layers.

persist in a dead fallen tree it is impossible to state, but the last figure given indicates a rather extended period in some cases. These cases refute the statements of Harkness (7) and Von Schrenk (26, p. 75) that the mycelium does not grow after the death of the tree.

On dead down trees the sporophores were never half bell shaped or ungulate, but were more typically near the subapplanate type.

Since so few cases of sporophores on dead fallen trees have been recorded during a rather extended period, it is safe to assume that infected fallen trunks are of slight importance from the standpoint of forest sanitation in infecting living trees through the production of sporophores.

Although sporophores are rather rare, an accurate indication of the place formerly occupied by a sporophore is supplied by the shot-hole cup (Pl. II), so termed and described by Meinecke (15, p. 23, 46). These shot-hole cups appear as cup-shaped depressions below a knot, the depression being riddled with numerous fine holes. At first they have the color of the freshly opened bark of the tree, but later become weathered and gray with age. They are formed in the following manner: The soft fleshy or cheesy sporophores issuing through knots are usually soon eaten by squirrels and microlepidopterous larvæ. Some of these larvæ then bore into the bark of the tree, where they are sought after by woodpeckers, which chop out a cup-shaped depression in the bark, corresponding to the place formerly occupied by the sporophores. This depression is riddled with what appear to be numerous fine shot holes, the burrows of the insect larvæ.

The presence of a shot-hole cup is just as reliable an index of dry-rot in a tree as is a sporophore. However, the same diagnostic values in relation to the age of the fungus plant in the tree, and consequently the extent of the resulting decay, must not be attached alike to sporophores and fresh and old shot-hole cups. An old, gray, weathered shot-hole cup would indicate the most extensive serious decay, while a fresh shot-hole cup, in turn, would indicate more extensive decay than a sporophore, since it is evident that more time must elapse before a shot-hole cup is formed than a sporophore and the longer the fungus plant lives in the heartwood the greater the amount of decay resulting.

The number of sporophores occurring on a standing living tree is typically one. Von Schrenk (27, p. 205) gives the number as usually one, but it must be remembered that at this time no description of *Polyporus amarus* had appeared, so it can not be stated definitely that Von Schrenk was referring to this fungus. However, Meinecke (15, p. 46, pl. 12) gives the number as typically one. Sometimes two have been found. As many as five shot-hole cups have been observed on a single living tree, but an examination of their con-

dition invariably showed that they had been developed successively, or at least not more than two in the same year. But on dead down trees the above rule does not hold. Of the seven known occurrences (see p. 9) several trees had two or more fresh sporophores.

During the course of the actual work of dissecting the trees exact data were secured on three sporophores and 17 shot-hole cups distributed on 15 trees, as follows: Two abortive sporophores on separate trees, one normal sporophore and two shot-hole cups on the same tree, 10 shot-hole cups on separate trees, 2 shot-hole cups on the same tree, and 3 shot-hole cups on the same tree.

That there might be a definite orientation of the sporophores in standing living trees was suggested by the work with *Trametes pini* of Möller (18), in which he found 89.4 per cent of the sporophores on the westerly side of the trees, attributing this to the facts that the prevailing winds were from the west, the trees were most strongly struck by rain on the west side, and therefore the branch stubs (a very common point of infection) were more moist on that side. Furthermore, he states that the sporophores appear at the same spot at which the infection commences. Weir and Hubert (32, p. 30), working with the Indian-paint fungus (*Echinodontium tinctorium*) on western hemlock (*Tsuga heterophylla*), found that most of the sporophores had a northwest to north-northeast orientation. However, the sporophores and shot-hole cups of *Polyporus amarus* are rather equally distributed to all points of the compass, showing no definite relation to any particular direction, and in not a single case was the sporophore developed at the same point at which the infection apparently commenced.

These sporophores and shot-hole cups occurred on trees ranging from 24.2 to 44.2 inches diameter breast high. The youngest tree which bore a shot-hole cup was 193 years old at stump height (1.5 feet), the next youngest was 221 years of age (28 years older), and the oldest, 379 years. Between the ages of 193 and 379 years the trees with sporophores or shot-hole cups were rather equally distributed. These figures are not given for the purpose of establishing a diameter breast high or age range for trees in which *Polyporus amarus* fruits; the number of trees examined forms entirely too meager a basis.

Sporophore formation did not seem to be in any way related to the width of the sapwood, since the sapwood in the trees which had formed sporophores varied from comparatively narrow in some cases to rather wide in others.

The heights at which the sporophores and shot-hole cups were found varied from 9.6 feet to 48.7 feet from the ground level, but thirteen of them occurred between 15 and 30 feet and only two at a greater height than the latter figure. Sporophores or shot-hole cups

always indicate that there is well-developed dry-rot in the heartwood. In such infections it is generally possible to distinguish three stages in the affected heartwood, with upper and lower limits. These stages for convenience are termed total extent, unmerchantable extent, and maximum concentration. "Total extent" is expressed by giving the height in feet in relation to the ground level of the lowest and highest point in the bole of the tree invaded by the fungus without regard to radial extent. By "unmerchantable extent" is meant the portion of the bole rendered valueless for lumber by the dry-rot, while "maximum concentration" covers that portion of the bole in which the decay seems to be at its worst. The upper and lower limits of all three of these stages may at times coincide, but especially that of the unmerchantable extent and maximum concentration. It is self-evident that these last two mentioned can never exceed the total extent.

The sporophores and shot-hole cups invariably appeared between the upper and lower limits of the maximum concentration. The lower limits varied from 3 to 25 feet below the sporophores or shot-hole cups, and the upper limits from 4 to 45 feet above them. In every case except one the lower limit of the unmerchantable extent was at 0. In other words the bole of every tree was unmerchantable, at least from the ground level to the sporophore or shot-hole cup. In the one exception the unmerchantable extent did not commence until 8.2 feet from the ground level. This was due to the presence of a large open fire scar extending from 0 to 10.8 feet. The fungus distinctly avoids the dried-out wood around open wounds, which habit will be fully discussed later in this paper. The upper limits of the unmerchantable extent were variable. In the two abortive sporophores the unmerchantable portion extended for 10 and 24 feet, respectively, above the sporophores, while the extent above the shot-hole cups was 23 and 53 feet.

The total extent in every tree with sporophores except one (see above, under unmerchantable extent) reached from the sporophore or shot-hole cup to the ground level, but the upper extent was variable, being for the two sporophores 24 and 25 feet, respectively, and for the shot-hole cups ranging from 24 to 53 feet.

From the figures available it is impossible to make an exact statement as to the range of the total extent, unmerchantable extent, and maximum concentration of the dry-rot in trees with sporophores or shot-hole cups, except that it may be safely assumed not only from the figures at hand but from observations on logging areas that the bole of a tree will always be unmerchantable from the ground level to a variable height above a sporophore or shot-hole cup. But it must be remembered that an old shot-hole cup indicates a greater development for the fungus plant in the tree than does the first

appearance of a sporophore or fresh shot-hole cup, and one should be influenced accordingly in judging the condition of a standing tree.

THE DECAY.

The dry-rot, described and pictured by Harkness (7), Von Schrenk (26, p. 68, pl. 2), and Meinecke (15, p. 46, pl. 12), is a very characteristic decay, most closely resembling the so-called peckiness of the eastern cypress (*Taxodium distichum*). Von Schrenk (26, p. 52-53) points to this analogy, even suggesting that the two diseases may be caused by the same fungus, but Long (12) has disproved this theory. The former investigator (29, p. 30) also calls attention to the macroscopical similarity between this dry-rot and the brown-rot of redwood.

Typically, the decay consists of vertically elongated pockets, varying in length from one-half inch to about a foot, which are filled with a brown friable mass, and the line of demarcation between the sound and decayed wood is very sharp. In some of these pockets small cobweblike or feltlike masses of white mycelium occur. The pockets are separated from each other by what appears to be sound wood, although in some cases streaks of straw-colored or brownish wood may extend vertically between two pockets. This is especially noticeable between young pockets. When immature the decay is faintly yellowish brown, soft and somewhat moist, and not broken up in the pockets. At times the mature pockets may be several feet long and rather broad; this type always occurs in connection with healed-over wounds, particularly healed fire scars in the butt of the tree. The decay has never been found in living sapwood and is usually confined to the heartwood of the trunk, but in very badly decayed trees the dry-rot sometimes extends into the heartwood of the larger limbs.

In the aggregate, the immature decay or advance rot extends but a short distance vertically in advance of the typical decay, and a distance of 2 feet beyond the last visible evidence of decay to the average eye will usually exclude all immature decay. This immature decay is very difficult to detect, occurring as it does in pockets, with the color in the very earliest stages differing but slightly, if at all, from the normal wood.

An occasional pocket may occur several feet in advance of the main body of decay, and while the wood of the pocket itself is of course greatly weakened, the intervening wood is probably very little affected, since the fungus hyphæ are very sparingly found between pockets of decay. In all, 566 trees containing typical dry-rot were dissected.

Typical dry-rot with small masses of white mycelium in some of the pockets is shown in Plate III.

STRUCTURE OF THE DISEASED WOOD.

The structure of the decayed wood in mature pockets was found to be practically as described by Von Schrenk (26, p. 70-71). In the very early stages of decay (immature pockets), cracks in the cell walls such as he describes for old pockets, which were most common in the pits, were rather rare. It was also found that cracks often started from the holes in the cell walls made by the hyphæ of the fungus. The color of the decayed wood varies from light to dark brown, depending on the state of decay.

In some of the decayed wood examined the bordered pits gave much the same appearance as is often presented by starch grains in a plant cell which have been partially corroded by diastase. Further examinations showed this condition of the bordered pits to exist in badly decayed wood, in slightly decayed wood, in the straw-colored wood between the pockets, and in sound wood. Immediately upon treatment with xylol, and more slowly with oil of turpentine, the pits resumed their normal smooth appearance; consequently, the condition is the result of a deposit on the membrane of the pits, but as to the nature of the substance deposited or the cause of its deposition the writer is unable to give any information. At least, the fact that the deposit was found on the pits in sound wood proves that it is in no way a result of the action of the fungus.

Badly decayed wood, slightly decayed wood, straw-colored and brownish colored wood between the pockets, and sound wood were treated with various reagents, the results in each case being practically identical. Anilin sulphate colored the cell walls a brilliant yellow. A cherry to violet-red stain was produced by treatment with phloroglucin and hydrochloric acid. Chloridid of zinc and alcoholic iodine with sulphuric acid both stained the walls a yellowish brown color. After treatment for 12 hours with Javelle water, the wood turned a yellowish brown upon the application of chloridid of zinc, and a brilliant yellow with the addition of anilin sulphate. The above tests demonstrate that the lignin compounds in the cell walls are not changed, in so far as our present knowledge of the nature of so-called lignin enables us to judge. Therefore, it seems probable that the fungus extracts from the cell walls either the cellulose or some other compound yet unknown.

THE MYCELIUM.

Hyphæ were very rare in the pockets of badly decayed wood or in the apparently sound wood immediately surrounding these. Proof of their having been quite commonly present, however, was afforded by the tiny holes in the cell walls of the decayed wood through which the hyphæ had passed. In the slightly decayed wood and the wood

immediately surrounding it hyphæ were found abundantly. They bore through the cell walls in all directions, showing no preference for the bordered pits and apparently making no distinction between spring and summer wood. They were rarely found in the medullary rays.

Harkness (7) states that "the mycelium does not leave behind the slightest microscopical trace of its presence in the sound wood when passing from pocket to pocket." In some of the brownish and straw-colored streaks of wood which extended vertically from pocket to pocket of immature decay, hyphæ were found sparingly. These usually followed the lumen of a tracheid, but sometimes passed through the wall into the lumen of the adjacent tracheid. The writer was unable to follow the entire course of the hyphæ in any case from pocket to pocket and therefore could not verify Von Schrenk's statement (26, p. 73) that "between the rotted areas the hyphæ usually extend directly from hole to hole." In some cases no hyphæ were encountered in the discolored streaks between the young pockets, but this was probably due to the failure to make sections at the proper place. Hyphæ were commonly present in the apparently sound wood surrounding young pockets to a distance of 4 mm. (0.157 inch), and sparingly from that point to 8 mm. (0.314 inch) in a horizontal direction. Owing to lack of proper material it was possible to make only a limited study of the vertical distribution of the hyphæ. In the case of the last (highest) pocket in a diseased tree the hyphæ were abundant to a distance of 1.5 cm. (0.6 inch) above the pocket, and sparingly from that point on to 7.8 cm. (3.07 inch), where they ended.

Observation leads to the inference that the hyphæ are able to pass for some distance through the sound wood without causing the slightest microscopical change in the color or structure other than an occasional hole in a cell wall as the hypha passes from the lumen of one tracheid to that of another. In certain cases isolated pockets of decay have been found at a maximum distance of approximately 4.3 meters (14.3 feet) from the nearest pocket of decay, yet a very careful analysis showed that there was only one possible means of entrance for the fungus into the tree, and consequently the hyphæ must have traversed this distance through the sound wood before causing another pocket of decay.

As to why the fungus decays only the wood in localized pockets which are separated by areas of practically sound wood it is impossible to state, since nothing is known of the influence of a possible variation of the chemical and physical properties of the wood on the fungus. Or it may be that the answer to the question lies in another direction; that is, the hyphæ in their work of destruction after a

certain time produce conditions unfavorable for their further development and are forced to seek another field.

In the wood the hyphæ are hyaline, varying in diameter from 0.8 to 3.3 μ but being most commonly 0.8 to 1.7 μ , branching and rebranching into the finest threads, anastomosing, sparsely septate, rarely constricted at the septa, and sometimes having clamp connections. They never become so abundant as to fill the tracheids completely. Usually the hyphæ pass from the lumen of one tracheid into that of an adjoining tracheid and then extend up or down the lumen, but occasionally a single hypha may cross several tracheids in a radial or tangential direction without extending up or down their lumens or giving off any branches. The holes in the walls of the tracheids made by the hyphæ are very small, particularly so since the hyphæ are often sharply constricted when passing through the walls. Rarely the hyphæ are irregular in shape.

The hyphæ composing the cobweblike and feltlike masses of mycelium in the badly decayed wood (see p. 13) are usually hyaline, but sometimes have granular contents. They vary in diameter from 0.8 to 40 μ , are richly branched, more commonly septate than the hyphæ found in the wood cells, and sometimes constricted at the septa. No clamp connections were found. They frequently anastomose. They were often very irregular in shape, and globose or spindle-shaped swellings were frequent.

OTHER FORMS OF DECAY.

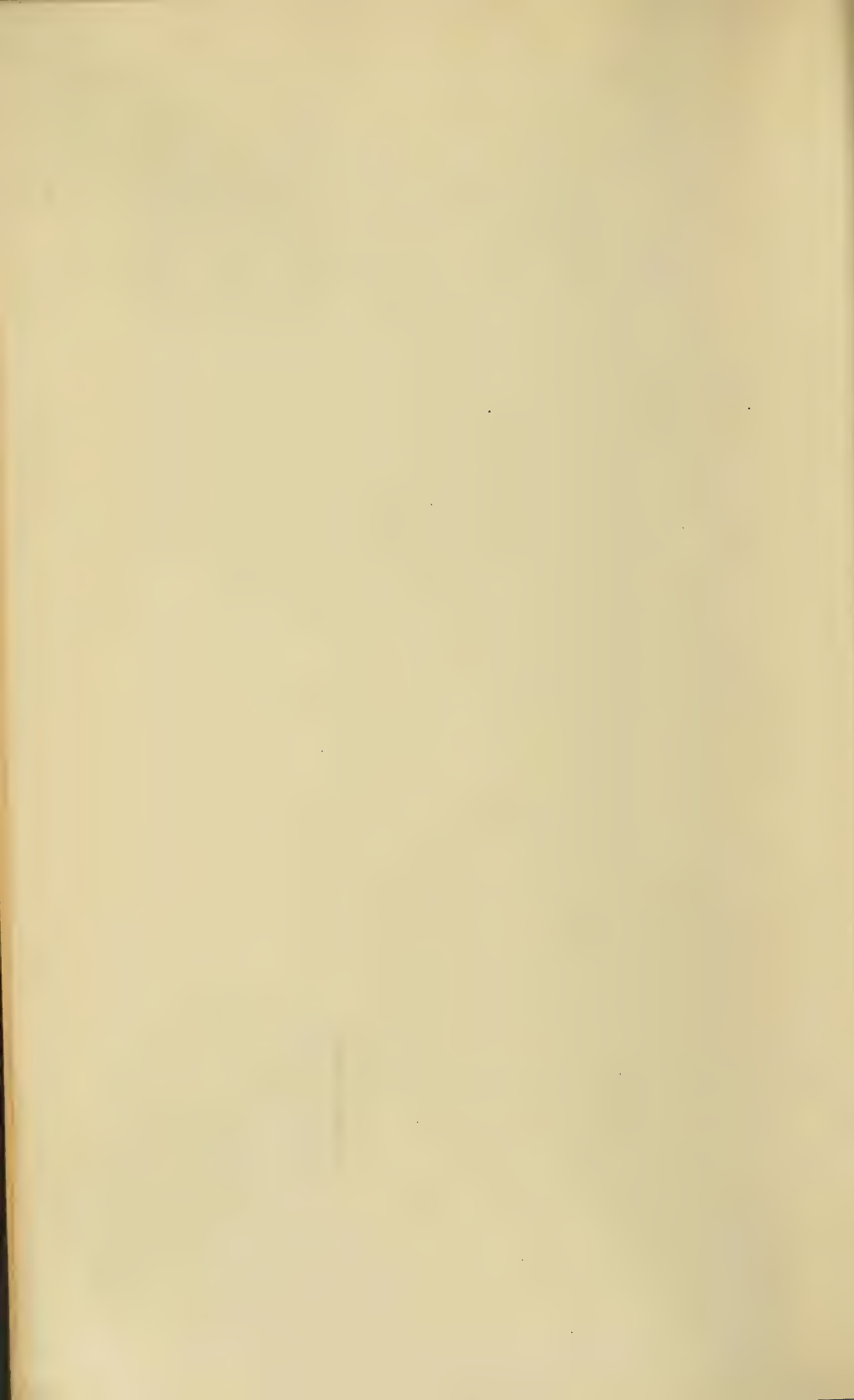
Besides the typical decay already described, two other very characteristic forms were found. One of these is characterized by small spots or pockets of brown decayed wood varying in width from 0.5 to 2 mm. (0.02 to 0.08 inch) and in length from 1 to 4 mm. (0.04 to 0.16 inch), with the long axis running vertically in the wood. In some cases larger decayed spots are formed by the joining of two or more smaller ones. The tiny decayed spots are separated by apparently sound wood. As for the structure of the decayed wood and its reactions with various reagents, these agree exactly with the typical form of dry-rot (see p. 14), and this decay is very probably an abnormal form of the typical decay caused by *Polyporus amarus*.

The other form of decay consists of very small white spots (measurements as given above) in which the wood has been reduced to cellulose, separated by apparently sound wood. The structure of the decayed wood is practically as described by Hartig (8, p. 53-54; 9, p. 36-37) for decay caused by the ring-scale fungus (*Trametes pini*), and the rot under consideration is undoubtedly caused by this fungus, since, through the courtesy of Dr. James R. Weir, the writer has been privileged to examine sporophores of *Trametes pini* with the typical



TYPICAL DRY-ROT IN INCENSE CEDAR CAUSED BY POLYPORUS AMARUS.

Photographed by Meinecke.



decay collected on incense cedar in Oregon. As far as the writer can ascertain, this is the only collection of its kind now known. Neither of these two decays affects the living sapwood.

The mycelium of both is the same and differs from the mycelium of typical dry-rot. Studies were made where these two decays were distinct, where they graded into one another, and where they graded into the typical dry-rot. The hyphæ vary from hyaline to dark brown in color, with a diameter ranging from 0.8 to 6.7 μ but most commonly 3 μ . The heavier brown hyphæ often branch profusely, the branches becoming smaller and lighter in color. The smallest ones are usually hyaline, and so are some of the larger hyphæ. In some instances the smaller hyphæ are merely continuations of the heavier strands. The hyphæ are sparsely septate, often constricted at the septa and without clamp connections. They bore through the cell walls in all directions, but seemingly more often through the tangential walls. No preference is shown for the bordered pits. They are characteristically sharply constricted when passing through the walls of the tracheids and have marked attachment organs. The hyphæ did not enlarge in the secondary lamellæ when boring through the wall, as is shown by Hartig (8, 9) for *Trametes pini*. Quite typically, a single strand may pass tangentially through as many as 20 or 30 tracheids, often completely traversing an annual ring, without sending any side branches into the lumens. This mycelium appears to agree closely with that described and figured by Von Schrenk (26, pp. 73-74, pls. 4-5), but which he assumed to be secondary and in no way connected with the dry-rot. Often the hyphæ seem to pierce a cell wall without developing in the lumen of the tracheid entered, a condition recorded by Hartig (8, p. 46) for *Trametes pini*. However, in so many cases unattached fragments of hyphæ were found in tracheids through the walls of which the hyphæ had penetrated without developing in the lumen that most probably the hyphæ did develop but were broken off in sectioning.

In all, 80 trees which contained one or both of these decays were dissected. The *Trametes pini* decay occurred alone in 61 of these, the dry-rot in small pockets in 11, and both forms in 8 trees. In 28 of the 61 trees having the *Trametes pini* decay, this was either intermingled, graded into, or very close to pockets of typical decay without there being any line of demarcation between the two. In certain cases the two decays could be absolutely traced to the same source of infection. Tree No. 40 on the intermediate area forms an excellent example. This tree had two small open fire scars in the butt just at ground level. There was a light infection of typical pockets of dry-rot extending from ground level to a height of 7.3 feet. At this point *Trametes pini* decay appeared without any line of demarcation and

extended to 29.4 feet, and then the typical pockets of dry-rot reappeared, which ultimately ended at a height of 41.4 feet. The only possible means of entrance for the two forms of decay were the small open fire scars at the ground level. A similar condition is presented in tree No. 7 on the intermediate area. This tree had a large open fire scar extending from the ground level to a height of 8 feet. Typical dry-rot entering through this open wound began at 6 feet, extending to 9.7 feet, where it merged into *Trametes pini* decay, which then gave place to the typical dry-rot at 14.7 feet, and the latter finally ended at a height of 20.7 feet. No line of demarcation could be distinguished between the two decays, and the point of entrance of the infection was at the open fire scar. Other examples could be cited, but these seem sufficient.

In the eleven trees in which the dry-rot in small pockets occurred it was either very close to or intermingled with typical dry-rot in six, and in four of these six trees both forms of decay could be exactly traced to a common point of entrance. There were no apparent lines of demarcation in any instance between the two forms of decay. In tree No. 392 in the intermediate range typical pockets of dry-rot extended from ground level to 28.7 feet. At this point the typical decay changed to the small pockets, and this form occupied the heartwood to 36.9 feet, where the decay stopped altogether.

Finally let us consider the eight trees in which both the dry-rot in small pockets and the *Trametes pini* decay were found. In two of the trees the two decays occurred in different parts of the bole. In two trees the decays were very close together, while in four trees the two were accompanied by pockets of typical dry-rot. Tree No. 296 on the intermediate area offers an excellent illustration of this last condition. In this tree the dry-rot in small pockets, the *Trametes pini* decay, and typical pockets of dry-rot were intermingled, and transition stages between the three forms were apparent from ground level to a height of 30.3 feet. In four of the eight infected trees it was possible to trace the entrance of both decays to the same point, healed fire scars. There were no lines of demarcation separating the various decays.

The interesting point in connection with the two forms of dry-rot and the decay caused by *Trametes pini* is that they occurred in the same substrata, either merging into one another or actually intermingling without any well-defined lines between them. That such lines of demarcation between different decays are the general rule has long been accepted and has been most recently expressed again by Weir (31). Hence, it is particularly interesting to find two exactly opposite types of decay intermingling so freely. It is quite probable, however, that such occurrences in the future will come to be recognized as quite common. The writer has already found

decays caused by *Trametes pini* and by *Fomes laricis* (the chalky quinine fungus) intermingled in the wood of living Douglas firs on several occasions, while down logs in the woods are often mycological gardens of wood-destroying fungi with the decays completely intermingled.

Both the dry-rot in small pockets and the *Trametes pini* decay are nearly always found around decayed knots or following along healed wounds, mainly those caused by fire. Where the infections occur around knots the decay is almost invariably confined to the immediate neighborhood of the knot, resulting in little or no loss in the merchantable contents of the tree. Where any appreciable quantity of wood was rendered unmerchantable, the decays were almost invariably in intimate connection with healed-over wounds caused by fire, frost, or lightning, particularly the first, throughout their extent. Exceptions to this rule did occur. In one tree, for example, the *Trametes pini* decay extended for a distance of 23.5 feet in the center of the tree above an open fire scar without being in connection with any other wound. But the fire scar was very large, extending deeply into the tree and undoubtedly had a far-reaching influence on conditions in the heartwood. In another tree (tree No. 40 on the intermediate area; see p. 17) this same decay extended for 22.1 feet in between two areas of typical dry-rot without following along any wound. The dry-rot in small pockets was found in one instance to extend for a distance of 8.2 feet, not in connection with a wound but merely as an extension of typical dry-rot. This case has already been cited (tree No. 392 on the intermediate area; see p. 18).

The above fact suggests that the dry-rot in small pockets may be the result of the influence on the dry-rot fungus of changed conditions in the heartwood, either physical, chemical, or both, induced by the presence of wounds or knots.

In further support of this hypothesis, it is almost invariably the rule wherever typical dry-rot is found along healed fire scars in the butt of a tree that instead of the pockets of normal size, one or more long continuous pockets of the dry-rot follow immediately along the scar throughout its length and invariably run out close to the end of the scar. A maximum length of 10 feet has been attained. Such pockets have never been found except in connection with wounds. This seems to prove that variations in the typical form of dry-rot may be induced by certain types of wounds in the tree.

The fact that the *Trametes pini* decay is usually found in the immediate vicinity of knots or healed-over wounds may be taken to indicate that incense cedar is an unsuitable host for *Trametes pini* and that the organism can rarely progress much beyond the point of infection. This would also explain the rare production of sporophores and the fact that in the only known collection, to cite Weir's

words in a letter to the writer, "The sporophores are of the small depauperate type which I find occasionally on trees at high elevations or on old punk knots from which the original sporophores have fallen and are reviving."

However, for the purposes of this paper these decays may all be treated as one and the same, since the dry-rot in small pockets and the *Trametes pini* decay are of negligible importance both in the number of infections and amount of cull resulting. Hence, except in the data on the rate of spread of the dry-rot, they are included in all subsequent pages with the typical decay of *Polyporus amarus*.

No relation was found between the width of the sapwood and the extent of decay; trees with wide and narrow sapwood seem to be equally affected with the dry-rot.

RAPIDITY OF SPREAD OF THE DRY-ROT.

Although the rapidity of the spread of decay caused by heartwood-inhabiting fungi in standing trees has always been of interest, very little work has been done on this line. Hartig (9, p. 115-116), mentions this briefly in relation to the rot caused by *Polyporus* (*Fomes*) *igniarius* in oak. More recently Münch (23) has published some interesting results from studies of the same fungus and host, showing a wide variation of 3.8 to 37.5 cm. (0.12 to 1.23 feet) in the yearly vertical progress of the decay, with an average of 5 to 9 cm. (0.16 to 0.30 of a foot). No tangible difference was found between the upward and downward rate of spread from the point of infection. Münch's results are based on an analysis of only 15 cases, and their value is further reduced by the fact that in determining the age of the infection which entered a tree through an open wound, he assumed that infection must have occurred the year the wound was made, or at least a very few years subsequently, even though the wound was still open at the time of analysis. True enough, as shown by Münch (23), *Fomes igniarius* attacks not only the heartwood but the sapwood of many trees and kills the cambium, causing cankers with subsequent callusing, and by counting the number of annual rings in the callus at the point of infection the age of the decay can be determined, provided a canker was formed the year of infection; but this is not uniformly the case, to judge from Münch's (23, p. 519) own statement that "*Fomes igniarius* produces exceedingly variable cankers. Sometimes small points of infection which are scarcely noticeable and are soon healed perfectly . . ."

In securing the figures on the yearly rate of spread of the dry-rot, only those infections were considered the entrance of which could be absolutely traced, without any other possibilities, to a healed scar for which it was possible to determine the exact dates of occurrence and closure. For example, an infection is found in a

tree which was cut in 1915. The fungus entered through a healed fire scar which occurred in 1781 and was completely closed by callusing in 1816. By subtracting 1781 and then 1816 from 1915 it is seen that the fungus has been in the heartwood a minimum of 99 and a maximum of 134 years. During this period resulting decay has progressed a vertical distance of 34.2 feet in the bole, or a yearly average of 0.25 to 0.34 of a foot. The radial extent of the decay is disregarded, since this is of little importance from a practical viewpoint. Any serious infection usually extends more or less throughout the heartwood in a radial direction. Of course, the above method does not give a single figure for the yearly average progress of the dry-rot, but it does give the exact minimum and maximum limits between which the true figure lies.

In all 99 infections were possible of analysis by this method. The great majority of these commenced at ground level, entering through fire scars and extending up the bole. Ten of the infections were traced to wounds high enough up on the trunk, however, to make possible a comparison of the upward and downward progress of the dry-rot. This meager basis indicated that the dry-rot, in the main, progresses more rapidly downward than upward, although in individual cases this relation may be reversed.

The yearly progress of the decay is exceedingly variable. At one extreme there is a tree in which the fungus had been vegetating between 124 and 135 years, but the resulting dry-rot had only attained a length of 0.4 of a foot, or a minimum average yearly progress of 0.002 and a maximum of 0.003 of a foot. The tree was 147 years old. At the other extreme, the fungus in from 10 to 58 years caused decay extending over 30.9 feet of the bole of another tree, that is, a minimum average progress of 0.53 of a foot a year and a maximum of 3.09 feet. This tree was 240 years old. Again, in a 107-year-old tree the fungus caused a decay with a minimum average progress of 0.87 of a foot and a maximum of 1.90 feet a year, extending a total of 40 feet vertically. In the main, however, the minimum progress of the dry-rot varied from 0.01 to 0.20 of a foot a year, while the maximum ranged from 0.01 to 0.35 of a foot. Higher yearly rates than the upper limits stated were not uncommon, but lower rates than 0.01 of a foot were rare.

These figures clearly demonstrate the slow progress of the dry-rot fungus in causing decay. Generally it required from 50 to 300 years to bring about any far-reaching dry-rot. In the heartwood of certain individuals the fungus had vegetated for decades, the resulting decay only extending 1 or 2 feet from the point of infection. A similar condition was found by Münch (loc. cit.) for *Polyporus (Fomes) igniarius* attacking oak. As to why the development of the dry-rot fungus in certain cases is so inhibited the writer is unable to present

any definite information, but certainly the chemical and physical condition of the substratum must have a strong bearing on this phenomenon. Hartig (9, pp. 115-116) believes in the case of *Polyporus* (*Fomes*) *igniarius* that the width of the annual rings of the wood is not without influence on the rapidity of decay. Münch (20, p. 156) states that the more rapidly grown coniferous wood, consequently that with the broader annual rings, is more speedily decayed by *Fomes annosus* than slower grown wood with narrower rings, even extending this to broad and narrow rings in the same individual. Later (22, p. 403-406), he shows that suppressed individuals of beech artificially infected with *Stereum purpureum*, *S. rugosum*, *Polyporus* (*Fomes*) *igniarius*, and *P. (F.) fomentarius* were more seriously decayed than dominant thrifty trees, yet it is just such suppressed trees which must have the narrowest annual rings. Finally (23, p. 521), the same investigator finds no relation whatsoever between the breadth of the annual rings and the rapidity of decay in the wood of oak attacked by *Polyporus* (*Fomes*) *igniarius*.

PURPLE COLORATION.

Accompanying the dry-rot is a purplish coloration of the heartwood which is very characteristic. The writer does not find this mentioned in any description of the dry-rot so far available, but it is well known to the lumberman. This color varies from a light salmon-red or pink to a pronounced purplish red in trees with heavy decay, where it may stand out strongly in cross section as a ring surrounding the decayed area or present a mottled appearance over the entire heartwood. Where the coloration is faint it is sometimes impossible to detect it in cross section, but if the tree is split longitudinally the color is readily apparent, although it often fades out entirely after several days' exposure to light and air. It usually commences at ground level and extends upward, but may start at varying heights.

Microscopical studies of this colored wood did not show any deviation from sound wood. No hyphæ were found except at points immediately adjacent to pockets of dry-rot. No chemical or physical examination was possible.

In all, 634 trees were dissected in which the purple coloration was present. The notes from Cow Creek did not include data on this coloration. The youngest tree in which the coloration was present had an age of 72 years, while the youngest tree cut was 52 years old. No attempt can be made to set a minimum age limit for trees with purple coloration, since not many trees were cut below the age of 70 years.

Of the 634 trees under consideration, the purple was present in 84 in which no dry-rot was found. In these the coloration, varying through all shades from a very faint salmon pink to pronounced red-

dish purple, usually began at the ground level, extending up the heartwood to a minimum height of 2.6 feet and a maximum height of 31.4 feet. Of these trees 39 had open or healed-over wounds, mainly caused by fire, offering or having offered a means of access for the dry-rot, but the remaining 45 were without indications of wounds, the only possible mode of entrance for the decay being through branch stubs. It would be highly improbable that all of these trees could be infected by the dry-rot fungus without showing any indications of decay, so the conclusion is obvious that purple coloration may exist unaccompanied by *Polyporus amarus*.

In all, 510 trees with typical dry-rot alone or in conjunction with secondary decay were worked up at Sloat, Strawberry, and Crockers Station. Notes on 25 of these were incomplete so far as purple coloration is concerned, so they drop out of consideration. All but 17 of the remaining 485 had purple coloration accompanying the decay. In certain cases the coloration did not extend over the entire decayed area, running out before the decay ended, or else isolated pockets of dry-rot were found outside the area of coloration. In the 17 cases of dry-rot unaccompanied by any coloration, the decay as a rule was negligible. In four of these trees, however, there was a loss in volume caused by the dry-rot of 7.1, 21.3, 39, and 67 per cent, respectively, without any coloration being visible, indicating that serious decay can exist apart from the purple coloration.

Of the 59 infections of the *Trametes pini* decay, 4 became impossible of consideration because of incomplete notes. Of the remaining 55, 12 were unaccompanied by purple coloration, but all of these except two were very superficial infections. Even in these two the amount of cull was very small. This decay had already been shown almost invariably to follow wounds in the trees; hence, it becomes quite reasonable to presume that the absence of purple coloration was brought about in most instances by the change in the physical or chemical condition of the heartwood induced by the influence of the wounds.

Where the typical decay and the *Trametes pini* decay were intermingled the coloration was almost invariably present, although not always throughout the entire infected wood. This was also the case with the brown dotlike pockets. However, these data should not be judged as more valuable than indications, since the number of cases available was relatively few.

Secondary rots comprised 43 infections; only 12 of these were in conjunction with purple coloration. The 31 without coloration only yielded one cull case; the amount of unmerchantable volume was very small, and furthermore these secondary rots were almost invariably in connection with healed or open wounds.

Hence, on account of the failure to find any microscopical evidence of fungous action in purple wood, the presence of dry-rot outside the area of purple coloration in certain trees, the frequent occurrence of extensive coloration in trees free from dry-rot, combined with the usual presence of the purple coloration in wood badly enough decayed by *Polyporus amarus* to cause a noticeable reduction in the merchantable contents of the individual tree, while it may be more often absent in light infections, the conclusion appears obvious that purple coloration is not a result of the action of the fungus, but, on the contrary, if it bears any relation whatever to the dry-rot, is merely a condition of the heartwood inducing favorable development of the vegetating hyphæ. The fact that the *Trametes pini* decay is more often unaccompanied by the coloration is offset by such infections usually being superficial and following wounds which probably exert a profound influence on the heartwood. No relation was found between the purple coloration and the width of the sapwood. Trees with sapwood varying from very narrow to very broad alike had the coloration in the heartwood.

RELATION OF DRY-ROT TO AGE AND CONDITION OF THE TREE.

From previous hints in the literature (22, p. 403-406; 23, p. 520; 16, p. 18-19, footnotes), Meinecke's preliminary study on incense cedar and his later work on white fir (16), it was reasonable to assume that some relation should exist between dry-rot and the age and condition of the tree; i. e., the degree of dominance and suppression.

Münch (22, p. 405), working with artificially infected red beech, found suppressed trees more susceptible to decay by *Polyporus* (*Fomes*) *igniarius*, *P. (F.) fomentarius*, *Stereum rugosum*, and *S. purpureum* than thrifty, dominant ones and explains this by the theory that the wood of suppressed trees contains a greater amount of air, consequently more oxygen, than thrifty dominants. In previous experiments the same investigator (19, 20, 21) had brought out the strongly favorable influence of oxygen in the host tissues on the development of wood-inhabiting fungi. Meinecke (16, p. 48) recognizes three periods in the life of white fir in its relation to the stringy brown-rot caused by the Indian-paint fungus (*Echinodontium tinctorium*): (1) The age of infection, at which "the infection rarely leads to more than negligible decay unless the tree is handicapped by quite unusually severe conditions, such as very large old wounds;" (2) the critical age, which "marks the point after which a combination of pronounced suppression and heavy wounding generally results in distinct decay;" and (3) the age of decline, "when even dominant (that is, thrifty) trees become subject to extensive and intensive decay." The relation between decay and suppression is brought out.

The crown class, as determined by observation of the standing tree, expresses the past history, more or less strongly modified by conditions prevailing through a varying number of years previous to the time of observation; it may not give the real past history of the tree. "Dominance" and "suppression" are really incorrect terms, used for lack of better ones. They are based on the relation of the height of one tree species to others in the same stand. In this case height alone would be misleading. For example, consider a more or less second-story species in a mixed stand, in which category incense cedar falls. Practically all the trees would be included in the intermediate or suppressed classes when related to other species in the stand, thus entirely obscuring the true relation of the individuals within the second-story species. On the other hand, it is an exceedingly difficult undertaking, often leading to grave error, to attempt classification by the observation of individuals in a mixed stand with relation to other individuals of the same species.

For our purposes we can not consider other tree species, but must compare individual trees with others of the same species. But here, also, height alone is not the deciding factor. Instead of giving dominance and suppression in the current meaning, these terms are expressed by the relation of the actual volume of the tree to the average volume of trees of the same age. Therefore, it was necessary to "curve" data collected on a number of trees to secure average volumes by age. Only trees of normal form with exact ages and free from severe wounds, malformations, and other seriously injurious factors which would interfere with the correct computation of the volume were used. Curves were constructed for the intermediate area and for the optimum area, since it was apparent that the volumes by ages would be much higher for the last-named areas than for the first, which fact was strongly brought out by the resulting curves. These curves are presented in figure 1, the higher curve based on 461 trees representing the optimum area and the lower based on 340 trees, the intermediate area. The National Forests on which these areas were located are also indicated. Thence, the trees for the intermediate area and for the optimum area were rated in regard to their respective curves, those with a volume higher than the average given by the curve for the same age being classed as dominant and those with a lower volume as suppressed. At first, an intermediate group was selected by designating an arbitrary volume above and below the average volume, trees between these limits being classed as intermediate. However, it was found that such trees inclined either toward the dominant or the suppressed in their characteristics, depending on whether they were above or below the average volume for the same age. Furthermore, it was exceedingly difficult

to determine just what the limits of the intermediate class should be, so in order to preclude any error in judgment the procedure as first stated of establishing just two classes, dominant and suppressed, to include all the trees, is followed throughout.

The method of obtaining the volume of the tree in cubic feet requires a little explanation. Each tree was considered as a perfect cone over the stump, at which the age count had been taken, in order to obtain directly comparable figures for the different ages. Figures from normal trees showing the relation of the diameter breast high to diameter of butt at stump height (1.5 feet) were plotted and curved, the strongest portion of this curve lying between 10 and 50 inches diameter breast high. From this curve a table expressing

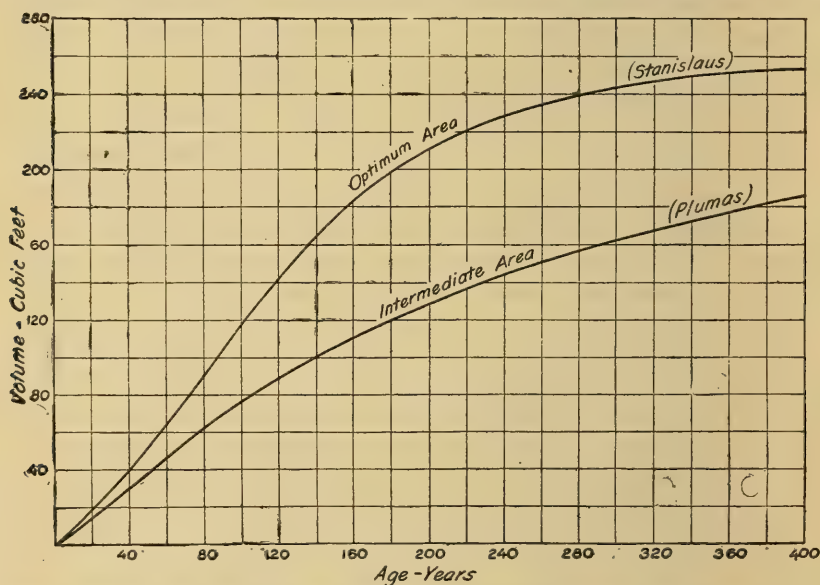


FIG. 1.—Comparison of average volumes of incense cedar on the optimum and intermediate areas.

the relation of the diameter breast high to diameter of butt at stump height for each inch class was read. It was then a simple matter to secure the diameter outside the bark at stump height for any tree, no matter how irregular the stump might be, due to wounds or other factors, and combining this with the height to work out the total cubic contents. Loss of volume caused by wounds or other factors was disregarded. In other words, each tree was treated as if it was absolutely normal. Let it be emphasized again that the volumes obtained were not meant to be an exact expression of the actual volume of each tree to the last cubic foot but merely had to be directly comparable to each other for the various ages.

In considering the trees with decay, each separate focus of dry-rot is termed an infection, and there may be two or more infections in

the same tree, each one, however, the result of a separate and distinct inoculation. As soon as an infection causes a measurable amount of cull it becomes a cull case and is so termed. Hence, every infection is not a cull case, but every cull case is an infection. Only loss of merchantable timber through dry-rot is considered; cull from wounds, knots, limbs, insect borings, or crook is disregarded, since these have no bearing on the loss from dry-rot except when the decay is directly traceable to a wound. In such cases loss from the wound is included with the volume of rot.

For figuring from the field notes and measurements the cull caused by dry-rot, the amount and degree of damage with relation to the resulting loss in merchantable lumber was carefully taken into account, just as it is in scaling. For example, a cull case might have considerable linear extent but consist only of a few scattered pockets in a straight line, resulting in little or no loss in merchantable volume. The same number of dry-rot pockets, shorter in linear extent but radially scattered throughout the heartwood, probably would cause considerable cull. Again, a number of pockets close to the sapwood, mostly slabbing out when the log is sawed, would have far less weight than the same pockets in the center heartwood. Meinecke's method (16, p. 37) of considering the entire bole of the tree over the linear extent of decay as cull, while justifiable with the commercially inferior white fir, could not be applied to the distinctly more valuable incense cedar. Here the lateral extent of the decay also had to be taken into account. This could be readily determined from the field notes and diagrams. For example, if the decay occupied one-fourth of the area as seen on cross sections and had a linear extent of 10 feet, the volume outside the bark of this 10-foot frustum (the tree being considered as a cone, see p. 26) was first secured and then one-fourth of it was considered as the volume of the decayed portion of the tree. Below one-fourth the decay was usually treated as negligible except when it had a linear extent of several feet. The volume was then computed as before.

Separate tables containing the above figures were worked up for the four areas, the trees being arranged progressively by ages, beginning with the youngest. It does not seem necessary to present these tables, since they were merely preliminary.

In considering the trees on the intermediate area it was found that the first infection which resulted in cull occurred in a tree 98 years old. However, infection can take place at a much earlier age than this. For example, in a tree 104 years old there was a light cull case traced to a healed lightning wound. The tree was injured at the age of 50 years and the wound completely healed when the tree was 63 years old; hence, the tree could not have been older than 63 years at the time of infection. Again, in a tree 146 years old there was a

serious cull case traced to a healed fire scar. This wound healed when the tree was 38 years old; hence infection could not have occurred subsequent to that age, since the field notes seem to exclude any possibility of an entrance of the dry-rot through a knot. Numerous other examples might be cited, but none of them reduces the minimum age of possible infection below 38 years.

An analysis of infections definitely traced to healed wounds in trees on the optimum area places the earliest age at which trees may be infected at 34 years, and this may be accepted as the age of infection for all the areas, since there is no apparent reason other than chance as to why the various areas should differ in this respect. Infections were very common between the ages of 45 and 80 years. No tendency was apparent toward an earlier age of infection in suppressed than in dominant trees, or vice versa. The foregoing figures are based on an analysis of 99 infections. Of course, this age may be even lower than here indicated, but it is evident that the earliest age of infection can not be lower than the age at which heartwood formation takes place in incense cedar. Just when this occurs is not definitely established, but observation seems to place it somewhere around 20 to 30 years. To be sure, there is a possibility of infection taking place in pathological heartwood resulting from an injury before the true heartwood is formed, the fungus mycelium vegetating in this type of heartwood until such time as true heartwood develops and then attacking it. While absolute proof of this course of procedure is lacking, observations have all tended toward substantiating the theory.

Furthermore, this age agrees approximately with that found by other workers with different species. Meinecke (16, p. 47) finds that for white fir (*Abies concolor*) decay caused by the Indian-paint fungus (*Echinodontium tinctorium*) "may show in trees 60 years old or perhaps younger," while Weir and Hubert (32, pp. 17-18), working with the same fungus in western hemlock (*Tsuga heterophylla*), set the average infection age for one type at 44.5 years and for another at 57.3 years. The figures are obtained by the use of a formula applied to the younger age classes. These same workers (33, pp. 11-12) place the "age of earliest infection" at about 50 years for western white pine (*Pinus monticola*) attacked by several common wood-destroying fungi.

Interesting as the determination of the age of infection or the age of earliest infection may be from an academic viewpoint, it is of little practical importance in this region. The questions of real import in this as in other species are the age at which decay begins to result in cull of economic importance and whether there is any relation between this and dominant and suppressed trees. The trees on the intermediate area and on the optimum area were first arranged

by 40-year age classes, grouping dominant and suppressed trees separately, and the percentage of dry-rot was determined for each age class. This was done by relating the total volume of dry-rot in each age class to the total volume in cubic feet of the trees in that age class. From these tables it was apparent that while there was no tangible difference between the amount of decay in the dominant and suppressed trees on the intermediate area, on the optimum area there was a decided difference, most strongly shown in the younger age classes, the dominant group having a lower percentage of decay than the suppressed trees.

That the trees in the intermediate area fail to bear out the relationship between suppression and decay indicated by the results of other workers on different species is after all logical. The reason for this is not hard to find. These trees are in the intermediate range for incense cedar, where the growth on the whole is relatively slow, and while they may be placed in dominant and suppressed groups within themselves, yet in relation to the trees in the optimum range they are slow growing, practically all being included under suppressed, with a few dominants. In other words, most of these trees are under the influence of regional suppression. Another glance at figure 1, which shows the great disparity between the volume-age curves for the two regions, brings this out more clearly. The term "regional suppression" is a new one. However, the concept which it embraces has long been advanced in ecology and silviculture. That there is a marked decrease in vigor and a decline in the rate of growth for each tree species outside its optimum, becoming greater as the distance from the region of best development increases, until finally the species becomes completely suppressed by other species either in or closer to their own optimum, has been pointed out by Mayr (13, pp. 73-79). This is exactly what has happened to incense cedar in the intermediate range. At best a second-story tree, in this region, away from its optimum, it has become, except for a few scattered individuals, badly suppressed by Douglas fir, Jeffrey pine, and yellow pine, which, while not in their own optimum, are yet closer to such a condition than the incense cedar. Mitchell (17, p. 33) recognizes how far this may go in suggesting that it may be advisable to eliminate the species entirely on the sites less adapted to it.

An analysis of the field notes reveals that this regional suppression is not due to a pathological condition, which might be suspected from the presence of the mistletoe (*Phoradendron juniperinum libocedri*) or of the needle and twig parasite (*Gymnosporangium blasdaleanum*).

A comparison of the trees on the intermediate area with the volume-growth curve for the optimum area resulted in the classification of only 38 out of the total of 495 trees as dominant. In other words, 457 of the trees on the intermediate area are actually suppressed when compared to the average for the optimum area.

It is not to be expected that the growth habits of the dry-rot fungus would vary to any extent in regions so closely related climatically as the intermediate and optimum ranges of incense cedar; therefore, it is reasonable to believe that no matter what the classification of the trees on the intermediate area may be in respect to dominance and suppression when compared with the volume-growth curve for that area, to find the true relation of the dry-rot fungus to dominant and suppressed trees it will be necessary to determine the classification of each tree by comparison with the volume-growth curve for the optimum area.

This is brought out in Table II, in which the trees from all the areas are combined, the dominance or suppression of all the trees being determined by comparison with the volume-growth curve for the optimum area. Only trees in which the progress of the decay or a fire scar did not make it impossible to determine the age at stump height are included in this table. This explains the slight discrepancy between the total number of trees dissected and the total number included in this and subsequent tables.

TABLE II.—*Cull caused by dry-rot found in incense cedars of the combined areas.*

Age class.	Number of trees (basis).		Average age.		Cull caused by dry-rot (percentage of the total volume).	
	Dominant.	Suppressed.	Dominant.	Suppressed.	Dominant.	Suppressed.
0 to 40 years.....	0	1	.....	40	.....	0
41 to 80 years.....	8	43	74	57	0	1
81 to 120 years.....	60	125	105	105	4	2
121 to 160 years.....	66	218	142	140	4	4
161 to 200 years.....	42	191	180	179	7	12
201 to 240 years.....	34	84	223	222	19	26
241 to 280 years.....	15	79	265	258	52	40
281 to 320 years.....	7	42	301	294	68	60
321 to 360 years.....	3	16	341	332	68	66
361 to 400 years.....	2	2	372	368	83	68
401 to 440 years.....	0	2	.....	436	.....	5
Combined.....	237	803	166	173	16	20

In Table II the dry-rot percentage in the age class 161 to 200 years, for example, is figured on the total volume of all the dominant trees both sound and decayed in that age class and not on the total volume of both dominant and suppressed trees. This is the method used throughout the table.

It will be noticed that the number of trees (basis) in the suppressed class far exceeds the dominant, this being a direct result of the influence of regional suppression on the trees of the intermediate area.

The columns of greatest interest are the last two, in which the dry-rot percentages of the dominant and suppressed trees in the different age classes are directly comparable. By dry-rot percentage is meant the percentage of cull caused by the decay resulting from

the work of the dry-rot fungus. The reader should remember that the percentage of cull based on the merchantable volume of the trees would be higher than the percentages here given, since these are based on the total volume of the trees outside bark and including the entire top. In the younger age classes up to 160 years the percentage of cull is small and variable, in one class higher in the suppressed, in another higher in the dominant, and in a third equal. But in the age class of 161 to 200 years a decided jump in the percentage of cull occurs, particularly in the suppressed trees. While the increase in the case of the dominants is only 3 per cent, in the suppressed trees it amounts to 8 per cent, bringing the cull percentage to 12. In the next age class a still further change is apparent. Here the cull percentage in the dominant trees increases strongly, as does also the percentage in the suppressed trees, the latter still remaining considerably higher than the former. But in those subsequent classes which have a sufficient numbers of trees to make the data of value, the cull is higher in the dominant than in the suppressed trees. When the age classes are combined, the total cull is 4 per cent more in the suppressed than in the dominant trees.

The salient features shown by Table II are the low percentage of cull in the younger age classes, the sudden increase earlier in the suppressed than in the dominant trees, which after it once begins goes steadily on with advancing age, and the higher percentage of cull in the suppressed trees as compared with the dominant trees in the two age classes which show the first sudden increase in this percentage.

However, the percentage of cull caused by dry-rot is not the only figure of interest, since it is prerequisite that the trees first be infected and that these infections develop sufficiently to cause measurable cull. Table III gives the figures on percentage of infection and cull cases. The number of trees used as the basis and the average age are the same as in Table II.

TABLE III.—*Infections and cull cases found in incense cedars of the combined areas.*

Age class.	Infections (percentage of total number of trees).		Infections causing measurable decay (percentage of total cull cases).	
	Dominant.	Suppressed.	Dominant.	Suppressed.
0 to 40 years.....		0		0
41 to 80 years.....	12	5	0	5
81 to 120 years.....	50	33	28	15
121 to 160 years.....	62	42	35	28
161 to 200 years.....	57	62	36	44
201 to 240 years.....	71	74	56	63
241 to 280 years.....	87	82	80	78
281 to 320 years.....	100	90	86	88
321 to 360 years.....	100	87	100	87
361 to 400 years.....	100	100	100	100
401 to 440 years.....		100		100
Combined.....	61	54	41	42

Table III shows that the percentage of infections is not in exact relation to the percentage of cull caused by dry-rot as given in Table II. In the age class of 41 to 80 years, while the percentage of infections is higher in the dominant trees the percentage of cull is slightly lower. In the age class of 81 to 120 years these percentages bear the same relation to each other as they do in all other classes except the classes of 121 to 160 years and 361 to 400 years. In the former there is a much higher percentage of infections in the dominant trees, while the percentage of cull is equal, and in the latter the percentage of infections is the same in both dominant and suppressed trees, while the percentage of cull is higher in the former. For all the age classes combined the percentage of infections is markedly higher in the dominant than in the suppressed trees.

Now, considering the columns relating to the total trees with cull cases, that is, where infections cause a measurable amount of decay, it is found that in the age class of 41 to 80 years none of the infections in the dominant trees result in cull cases, while all of the infections in the suppressed trees do, thus accounting for the higher percentage of cull in the suppressed trees in that class. In the next age class (81 to 120 years) the dominant trees have almost twice as many cull cases as the suppressed, and the percentage of cull is just twice as great in the former. But in the age class of 121 to 160 years, while the cull cases are in a higher percentage in the dominant trees the percentage of cull is equal in the two classes, showing that there is more loss per cull case in the suppressed than in the dominant trees. In the subsequent age classes the cull cases and the percentage of cull are in the same general relation except in the age class of 361 to 400 years, where the difference is the same as explained for the infections. The total cull cases for the suppressed trees is only 1 per cent higher than for the dominant trees.

The idea might have been advanced that since inoculation by spores of any wood-destroying fungus is to a certain extent a matter of chance, the greater percentage of cull in the suppressed trees might have been due to a greater number of infections in these trees. But Table III shows more infections in the dominant trees, while the cull cases are about equal in both. Therefore the cull cases must be more severe in the suppressed trees.

The infections, or even the cull cases, do not show the same progression through the age classes from the youngest to the oldest as is shown by the cull percentage. In the former the sudden, sharp increase in the age class of 161 to 200 years for the suppressed and in the class of 201 to 240 years for the dominant trees is not apparent. The increase is more regular throughout, thus indicating that there is an influence other than merely the number of infections which has

a strong bearing on the development of cull cases and the percentage of cull.

Since neither the total number of infections nor cull cases follows the same law as the percentage of cull, it is self-evident that there must be an exact relation between this last and the more extensive or severe cull cases. Accordingly, in Table IV the severe cull cases, that is, those cases in which one-third or more of the total volume of the tree is a loss through dry-rot, are considered separately. The same basis is used as in Tables II and III and the percentages are based on the number of trees in the dominant and suppressed groups considered separately in each age class.

TABLE IV.—*Relation between dominant and suppressed trees in severe cull cases found in incense cedars of the combined areas.*

Age class.	Severe cull cases (per cent).		Age class.	Severe cull cases (per cent).	
	Dominant.	Suppressed.		Dominant.	Suppressed.
0 to 40 years.....		0	281 to 320 years.....	71	66
41 to 80 years.....	0	0	321 to 360 years.....	67	81
81 to 120 years.....	3	2	361 to 400 years.....	100	50
121 to 160 years.....	2	2	401 to 440 years.....		100
161 to 200 years.....	5	14			
201 to 240 years.....	26	31	Combined.....	14	17
241 to 280 years.....	73	48			

In Table IV is seen the same form of progression for the severe cull cases as was shown for the amount of cull in Table II. Low percentages in both groups up to an age of 160 years, with a sudden increase in the percentage of severe cull cases in the age class of 161 to 200 years for the suppressed group are followed by a like increase in the class of 201 to 240 years for the dominant trees. After 240 years is passed there is a higher percentage of severe cull cases for the subsequent age classes in the dominant group, just as is the case for the percentage of cull. The only exception to this is found in the class of 321 to 360 years, where the relation is reversed.

The outstanding fact shown by Tables II, III, and IV is that incense cedar during the earlier stages of its life, even though heavily infected, is able to retard the progress of the dry-rot fungus in causing decay. Then comes a period, earlier in the case of suppressed than of dominant trees, at which the progress of the fungus can no longer be held in check and the trees become subject to severe decay, with the accompanying high percentage of cull. In other words, the decay becomes extensive. This period occurs in the age class of 161 to 200 years in the suppressed group and in the age class of 201 to 240 years in the dominant group. An analysis of the individual trees, in a table which is too long to present here, reveals the fact that this change begins at 167 years in the suppressed and at 214 years in the dominant trees,

At these ages extensive decay, as represented by severe cull cases, becomes common in the individuals of the respective groups. These ages, using Meinecke's nomenclature, may be termed the "critical age" and "age of decline" for incense cedar—that is, the ages at which suppressed trees and dominant trees, respectively, become subject to extensive decay. Meinecke found a combination of severe wounding and pronounced suppression both contributing to the critical age in white fir, but in incense cedar wounding is not necessarily a factor. This will be brought out later when mechanical injuries are considered.

After the age of decline is passed, as shown by the percentage of cull in the classes older than 240 years, the dry-rot is more extensive in the dominant than in the suppressed trees. This means that while the dominant trees are able to ward off the extensive development of the dry-rot fungus for a longer period than the suppressed trees, after the age of decline is once passed dominance ceases to be a factor in resisting decay and, in reality, seems to favor it. This may be due to the fact that in the old, overmature dominant trees there is a higher percentage of food material (i. e., heartwood) for the fungus to work on in relation to the total volume than in the case of the suppressed trees. The fungus does not attack sapwood.

Let us consider what the foregoing paragraphs mean from a practical standpoint. Roughly, we may place the critical age at 165 years and the age of decline at 210 years. This does not mean that there is no loss from decay previous to these ages, or even that there are no severe cull cases; but the latter are so rare, as shown by Table IV, that they may well be regarded as exceptions. Since all but a very few of the trees on the intermediate area are suppressed, taking this area as representative for the intermediate range we can not expect trees within this range to remain free from extensive dry-rot after they have attained the age of 165 years. In the optimum range this same age may be set for suppressed trees, while dominants will remain relatively sound until the age of 210 years is reached. On the optimum areas dominant individuals comprised 36.5 per cent of the total, but on the intermediate area only 7.6 per cent.

No relation was found between diameter breast high and dry-rot. This could hardly be expected, considering that incense cedar is a tolerant species in an uneven-aged mixed stand.

In Tables II, III, and IV the comparison of the dominant and suppressed trees in their relation to the percentage of cull due to dry-rot has been emphasized to the neglect of other considerations in which the same relation might be found in both groups. In Table V many of the data given previously but separately for the dominant and suppressed groups are combined.

TABLE V.—*Combined data relating to dry-rot found in incense cedars of the combined areas.*

Age class.	Average age (years).	Number of trees (basis).	Percentage of—			
			Dry-rot volume.	Severe cull cases.	Cull cases.	Infections.
0 to 40 years.....	40	1	0	0	0	0
41 to 80 years.....	60	51	1	0	4	6
81 to 120 years.....	105	185	3	3	20	38
121 to 160 years.....	141	284	4	2	29	46
161 to 200 years.....	180	233	10	12	42	61
201 to 240 years.....	223	118	22	30	61	73
241 to 280 years.....	259	94	44	52	79	83
281 to 320 years.....	296	49	62	67	88	92
321 to 360 years.....	334	19	67	79	90	90
361 to 400 years.....	370	4	82	75	100	100
401 to 440 years.....	436	2	5	0	100	100
Combined.....	171	1,040	18	17	42	56

Table V strikingly demonstrates the cumulative risk to incense cedar from dry-rot with advancing age. Starting at 1 per cent of cull in the age class of 41 to 80 years it mounts to 67 per cent in the class of 321 to 360 years. With a very gradual increase up to 160 years it then becomes rapid. The figure of 82 per cent in the class of 361 to 400 years, even though on an insignificant basis, is not without significance when considered in relation to the general previous progression. That this figure should drop to 5 per cent in the last age class need not cause concern, since the basis is only two trees. Even though infected, a tree may escape extensive decay throughout its life. This is a rare occurrence, however. The percentage of severe cull cases closely follows the percentage of cull throughout until the last two age classes with their small bases are reached. These two sets of figures show beyond doubt the high percentage of loss through dry-rot that may be expected in overmature cedars and clearly prove that the presence of such trees in our stands of the present and the future can be nothing but an economic loss.

That the percentages of cull cases and of infections do not follow the same form as the two others just discussed was shown in previous tables, but is more clearly brought out here. The reasons for this have been touched upon. However, these two figures are of interest when compared. It is seen that with advancing age the percentage of cull cases becomes increasingly higher at a more rapid rate than does the percentage of infections, until finally in the class of 321 to 360 years the two coincide. To be more explicit, the infections gradually begin to cause more and more measurable decay, until finally every infection has resulted in a cull case, no matter how slight. In the last two age classes both cull cases and infections have reached 100 per cent; but again we are confronted by the small basis and this figure can not be accepted. There is no doubt that a tree by rare chance may escape infection throughout its life, but there is hardly

any possibility that when once infected sooner or later some cull will not result.

To make the relation just discussed even more apparent the four sets of data have been plotted in figure 2. From this, it can be seen that the form of the curves for severe cull cases and cull are the same, but differ quite markedly from the curve for infections. This shows clearly that infections alone are not the sole influence on the development of the dry-rot fungus, for if so the curves would have the same form. The slow progress of the dry-rot in the younger trees is very apparent.

The curve for the cull cases is somewhat intermediate, at first inclining toward the severe cull cases and later coinciding with the infections. The younger trees are able to retard the fungus suffi-

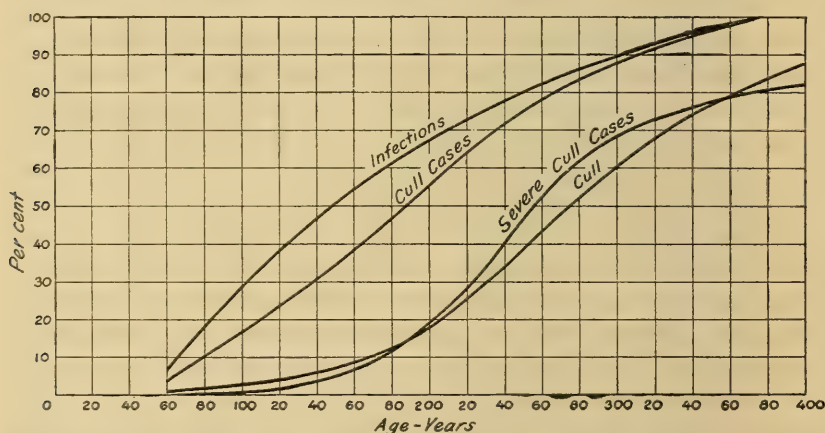


FIG. 2.—Relation of the age of incense cedar trees to infections, cull cases, severe cull cases, and cull.

ciently to prevent many of the infections from developing into cull cases, but later this characteristic is obscured.

The relative percentages of cull due to dry-rot on the various areas is not of importance from the standpoint of the present investigation. That this will vary widely even within the optimum and intermediate ranges is self-evident to anyone who has been on logging operations where incense cedar is being cut. At times the variation, even in localities quite close to each other, is surprising. On the intermediate area the cull for all the trees amounted to 20.5 per cent, while for the optimum area the figure was 16.8 per cent. These figures must not be taken as absolute, since it must be remembered that the areas were not clear cut. Practically every tree between the ages of 100 and 240 years was cut except those in which it was apparent that the age could not be accurately determined. Not all the trees below 100 years or over 240 years were cut, however, since this would have meant an enormously increased cost

without adding much to the investigation, the chief aim of which was to determine the age at which dry-rot became extensive and far-reaching. However, the relative representation of trees in the older age classes was maintained as far as possible, neglecting entirely, of course, the few very old veterans always found scattered through a virgin stand.

The cull percentages given are indicative of the relative conditions that will exist in the intermediate and optimum ranges, although stands in the latter will on the whole be relatively more free from dry-rot than our figures indicate. However, the Office of Forest Pathology is now collecting figures for cull percentage by a less intensive method over various localities, and these will include not only cull due to dry-rot but to all other causes as well.

Before drawing final conclusions there is one other factor which must be considered in relation to dry-rot, namely, wounds or mechanical injuries.

MECHANICAL INJURIES.

The mechanical injuries which must be reckoned with are those caused by fire, frost, lightning, and the breaking off of branches as well as such miscellaneous factors as snow, falling trees, mammals, and wind. These injuries are important from three standpoints. First, they often afford an entrance to the heartwood of the tree for spores of wood-destroying fungi; next, the growth processes of a tree may be somewhat interfered with, resulting in a lessening of increment and a consequent tendency to suppression; and, last and least important, an actual loss in merchantable volume may result from the mere presence of the injury.

Spores of the dry-rot fungus (*Polyporus amarus*) must have an entrance to the heartwood before they can germinate and develop. As long as the tree is protected by a layer of bark and sapwood it is immune from the ravages of dry-rot or any other heartwood destroyer. Small superficial wounds are quickly protected by resin exudation from the bark, which forms an antiseptic dressing on the wound, safeguarding it from fungous spores until the wound is finally healed or callused over. But incense cedar is poorly supplied with resin. Normally it is found in a limited quantity in the bark only, active in the inner bark, dry and hard in the outer bark. Large superficial wounds may often prove to be serious. If the bark is torn off over a large surface there is not enough resin available to form a dressing, the sapwood dries out and cracks into the heartwood, and these cracks offer an entrance for fungous spores. The most serious type of wounds, of course, are those extending deep into the heartwood, for then the heartwood is directly exposed to infection by wood-destroying fungi for the entire period of time

from the occurrence of the injury until it is completely healed over, and such injuries heal slowly. Wounds heal much more rapidly in young than in mature or overmature trees.

The causes of wounds are taken up in the order of their importance.

FIRE.

The most serious wounds, both numerically and in regard to the type of injury, result from fire. It is almost impossible to find a stand of timber anywhere in the Sierra Nevada or Coast Ranges which has not been visited by repeated fires. While the thick bark characteristic of incense cedar combined with the lack of resin in the wood makes it somewhat fire resistant, yet broad fire wounds commencing at ground level, reaching some distance up the trunk, and extending deeply into the heartwood are very frequent. These wounds are usually roughly triangular in shape, the base being at ground level and the apex at the top of the extent of the scar on the tree trunk. Considerable loss in merchantable timber results from the actual destruction of the wood, and there must be an appreciable decrease in increment until the tree readjusts itself to the loss in conducting tissue caused by the partial destruction of the sapwood and inner bark, which interferes with the conduction of water and soluble salts from the roots to the foliage and the return of elaborated food from the foliage to the roots. This loss is exceedingly difficult to gauge. Total loss in the merchantable timber occurs when a tree is completely girdled and killed or when the supporting tissue is so weakened by the wound that the tree is blown down.

Large fire scars or "catfaces" are rarely caused by only one fire, but usually by successive fires, each one hollowing out the heartwood a little more. As many as 10 distinct fires have been found contributing to the formation of one catface. As long as the wood is completely covered by a charred surface the danger of inoculation by fungous spores is reduced to the minimum, but the wood dries out and checks, forming cracks extending into the unburned wood. In time, the charred surface is weathered away, and finally the heartwood is exposed over the greater surface of the catface. Here is offered an excellent place for the entrance of a heartwood-destroying fungus.

Wounded trees make strong efforts to callus over the injury, and this is often accomplished in course of time if the wound is not too large. Very large catfaces, particularly on mature or overmature trees, are rarely healed over. The prevalence of wounds caused by fire may be seen from Table VI.

Table VI clearly shows that fire injury was much more serious on the intermediate area than on the optimum area. The columns of greatest interest are the third and last. The third column (per-

centage with open fire scars) shows that of the total number of trees analyzed on the intermediate area, 38.3 per cent had open fire scars, while on the optimum area the percentage is only 23.5. In other words, these percentages of the total number of trees cut on the areas under consideration were still exposed to infection by wood-destroying fungi through fire scars alone. The last column indicates that 72.2 per cent of the trees on the intermediate area and 49.3 per cent of those on the optimum area have had open fire scars at some period of their life history, thus exposing them to inoculation by fungous spores.

TABLE VI.—*Incense-cedar trees found in the combined areas having fire scars.*

Locality.	Number of trees (basis).	Trees with fire scars (per cent).			
		Open.	Internal.	Miscellaneous. ¹	Total.
Intermediate area.....	509	38.3	33.2	0.8	72.2
Optimum area	566	23.5	25.4	.4	49.3
Combined.....	1,075	30.5	29.1	.5	60.1

¹ Includes wounds probably but not certainly caused by fire. .

The internal scars on the intermediate area exceeded those on the optimum area by less than 8 per cent, but there were 15 per cent more open scars. This points to the fact that the intermediate area has been visited by more serious fires than the other, since, as has already been pointed out, large catfaces are normally the result of repeated fires.

The combined figures for all the areas show that a total of 30.5 per cent of the trees had open fire scars, while 60 per cent suffered fire injury at some time. The column headed "Miscellaneous" includes trees with scars not identified beyond all doubt as having been caused by fire. These are so few that they need not enter into the interpretation of the figures.

FROST.

Frost causes some injury in incense cedar but is not nearly as serious in this respect as fire. Frost cracks as a rule extend for some distance up the tree and go deeply into the heartwood. A common place for the cracks to commence is just at the apex of an open fire scar, apparently a point of weakness in the tissues of the wood. Often they are somewhat spirally twisted around the trunk, distinctly reminding one of typical lightning scars. While frost cracks present only a very narrow opening for the entrance of fungous spores, yet in length those cracks or clefts are often quite extensive. In many cases the wood around a frost crack is badly discolored, causing considerable loss in the merchantable contents of the tree.

Typical frost cracks are rarely found except on large trees. Table VII shows the percentage of frost cracks on the trees analyzed.

TABLE VII.—*Incense-cedar trees found in the combined areas having frost cracks.*

Locality.	Number of trees (basis).	Trees with frost cracks (per cent).		
		Open.	Internal.	Total.
Intermediate area.....	509	4.12	3.14	7.26
Optimum area.....	566	1.41	.53	1.94
Combined.....	1,075	2.70	1.77	4.47

Here again, as in the case of fire, the wounding is worse on the intermediate than on the optimum area. The percentage of trees exposed now or in the past to inoculation by fungous spores through the medium of frost cracks is rather low and not of great importance on any of the areas. Frost cracks in incense cedar are not nearly so prevalent as Meinecke (16, p. 31) found for white fir.

LIGHTNING.

Incense cedar suffers only slightly from injury by lightning. This is to be expected, since the dominant species in a stand and as such the taller trees (25, p. 36) are most subject to lightning stroke, while incense cedar rarely attains this position in the mixed stand in which it is found. Plummer (25, p. 33) also shows that incense-cedar wood is a poor conductor of electricity.

An incense-cedar tree in the forest badly shattered by lightning is an exceedingly rare sight and immediately provokes comment. However, trees with slight lightning injuries are more common. Such injuries show as superficial wounds on the trunk. Often the wood is not scarred, but the bark and cambium are killed. The bark then drops away, exposing the sapwood, which in turn dries out and checks, offering fungous spores access to the heartwood. Long wounds extending spirally around the tree, so common in white and red fir in this region, are an unusual occurrence on incense cedar.

Table VIII indicates the prevalence of lightning scars.

TABLE VIII.—*Incense-cedar trees found on the combined areas having lightning scars.*

Locality.	Number of trees (basis).	Trees with lightning scars (per cent).		
		Open.	Internal.	Total.
Intermediate area.....	509	1.76	2.53	4.31
Optimum area.....	566	3.54	1.06	4.60
Combined.....	1,075	2.70	1.77	4.47

Besides the trees shown in Table VIII, there were seven on the intermediate area and five on the optimum area with slight wounds which appeared to have resulted from lightning; but an absolute determination was impossible. The meager basis in this table shows practically an equal number of lightning-scarred trees in the two localities.

BREAKING BRANCHES.

Incense cedar does not prune itself easily even when growing in a dense stand, a fact attested by the persistence of the lower limbs. In time, however, some of the lower branches die and break off. The dead stubs then offer a point of entrance for heartwood-destroying fungi; the spores lodging in the dead wood may germinate, develop, and the fungous hyphæ pass through the bark and sapwood of the tree into the heartwood by way of the pin knot. The pin knot in this case plays exactly the same rôle as an open wound, but it must be remembered that the area for lodgment of a fungous spore on a pin knot that is not healed over is exceedingly small in comparison with other types of wounds. On the other hand, there are normally from several to many open pin knots on each tree, and every tree, throughout all but the earliest years of its life, is thus exposed to inoculation by fungous spores through these open pin knots. Many of course heal over, but others take their places.

OTHER CAUSES.

Besides the causes of wounds already discussed, there are a few others of minor importance.

Strong winds will occasionally break off branches or tops, or overthrow entire trees, particularly those weakened by a bad open fire scar in the butt. The thick foliage of incense cedar collects a very heavy weight of wet snow, often causing the tops and branches of young trees especially to break off. Sometimes a falling tree will rake off the limbs and part of the bark of a neighbor. Such injuries are usually superficial unless very large branches have been broken off or the bark has been torn away from the trunk over a considerable area.

Man is at times directly responsible for certain wounds. It is quite a common sight along a newly constructed road to see bark torn off, often rather high on the trunk, where the tree has been struck by a flying rock from a powder blast. Some wounds result from blazing trees to mark a boundary line or trail, but they are usually small and rapidly heal over.

Broken or dead tops, the cause of which is often impossible to determine, are not at all rare. Trees with these injuries comprised 6.9 per cent of the total number on the intermediate area and 7.1 per cent on the optimum area.

PREVALENCE OF INJURIES.

Most incense cedars do not attain any great age or size without suffering some injury. Many old trees, and more rarely young ones, show numerous injuries, often fire, frost, and lightning having combined in the wounding of a single tree. Of the 509 trees on the intermediate area only 116, or 22.8 per cent, escaped without injury, while on the optimum area 38.9 per cent, or 220 of the total 566, were free from wounds. This difference is explained by the fact that the risk from injury has been greater on the intermediate area than on the optimum area, while a greater number of young trees were cut on the last-named area than on the first. The risk of injury is cumulative, increasing with the age of the tree.

This cumulative risk of wounding is shown clearly in Table IX, in which the trees from all areas are combined and arranged by 40-year age classes. Only those trees the ages of which it was possible to determine exactly are included in this table, while the data on wounds previously presented include all the trees. This accounts for the apparent slight discrepancy between the figures on the total number of trees involved.

TABLE IX.—*Incense-cedar trees showing cumulative wounding in the combined areas.*

Age class.	Number of trees (basis).	Total with wounds (per cent).	Trees with severe wounds (percentage of total wounds).	Age class.	Number of trees (basis).	Total with wounds (per cent).	Trees with severe wounds (percentage of total wounds).
1	2	3	4	1	2	3	4
0 to 40 years.....	1	0	0	281 to 320 years.....	49	98	62.5
41 to 80 years.....	51	29.4	6.7	321 to 360 years.....	19	100	68.5
81 to 120 years.....	185	48.6	14.4	361 to 400 years.....	4	100	100
121 to 160 years.....	284	59.2	28.6	401 to 440 years.....	2	100	50
161 to 200 years.....	233	74.3	35.2				
201 to 240 years.....	118	82.2	44.4	Combined....	1,040	67.6	36.3
241 to 280 years.....	94	92.6	43.6				

In considering the figures in Table IX the reader should keep in mind the fact that since branch stubs are not treated as wounds, wounded trees practically mean fire-scarred trees, as the number of wounds from causes other than fire have been shown to be insignificant.

Considering column 3, which expresses the ratio of the wounded trees to the total trees, it is seen that the trees are subject to considerable wounding at a very early age and that this percentage increases very rapidly, until in the older age classes every tree has been wounded and consequently at some time exposed to infection.

Not only does the total number of wounds increase with age in a stand, but the number of severe wounds becomes proportionately greater. Each tree was given a wound rating (x), x, xx, or xxx, the first symbol indicating very slight wounding and the last very severe. In Table IX trees with a rating of xx or xxx are considered as severely wounded. In all cases the character as well as the extent of the wounding and its relation to inoculation by spores of the dry-rot fungus was carefully taken into account in applying the rating.

In column 4 of Table IX it is seen that while in the age class of 41 to 80 years only 6.7 per cent of the wounded trees are severely wounded, an almost steady increase brings this figure to 68.5 per cent in the class of 321 to 360 years. This is to be expected, especially since fire scars predominate, because large scars of this type are almost invariably the result of recurring fires, and in the past virgin stands in California have been fire swept time and again. The two oldest age classes can not be given much weight, owing to an insignificant basis.

The above figures demonstrate the rather slight chance an incense cedar has of rounding out its life without a reduction in its normal increment through an injury interfering with the growth processes or a reduction in its actual content of merchantable timber, either directly from a wound or by a wound affording an entrance for a heartwood-destroying fungus, in this instance most probably the dry-rot fungus (*Polyporus amarus*).

RELATION OF DRY-ROT TO MECHANICAL INJURIES.

The intimate connection of various kinds of wounding, especially fire, with infection by the dry-rot are shown in Table X. The infections are grouped under their respective causes and percentages for each cause, figured on the basis of the total number of infections. Trees of uncertain ages are included in these figures, since it makes no difference in this table whether or not the absolute age of the tree is known.

TABLE X.—Mode of entrance of dry-rot infections of incense-cedar trees.

Locality.	Number of infections (basis).	Means of entrance of infections (per cent).						
		Fire scars.	Knots.	Wounds, cause un-known.	Lightning scars.	Un-known causes.	Frost cracks.	Broken or dead tops.
Intermediate area.....	322	75.8	19.3	0.6	2.5	0.9	0.6	0.3
Optimum area.....	334	58.7	31.1	5.1	1.5	2.4	.9	.3
Combined.....	656	67.1	25.3	2.9	2.0	1.7	.8	.3

Table X shows that on the intermediate area nearly 76 per cent of all the infections entered through fire wounds; this means of entrance for the optimum area is approximately 59 per cent, while for all the areas combined it is almost 70 per cent. Since fire scars are almost invariably found in the base of the tree, commencing at ground level, these figures are at variance with Von Schrenk's (26, p. 69) idea that "the decay begins somewhere in the upper part of a tree."

Besides fire wounds being responsible for such a high percentage of the infections, inoculations through wounds of this character quite commonly lead to very serious and damaging dry-rot, even in some of the younger trees. In many cases, even in old trees, a long continuous pocket of dry-rot, sometimes having a linear extent of 10 feet, will follow a healed fire scar, running out at the end of the wound, with no further decay extending up the tree. Such infections do not appear especially serious, but it must be remembered that the most valuable portion of the trees, the heartwood in the butt log, is damaged. On the other hand, the fungus evidently finds conditions highly unsuitable in the wood back of a large open fire scar. Almost every tree with this type of wound appeared sound on the stump when felled, but serious dry-rot appeared at the first cut above the open fire scar. When such logs were split, it was found that the pockets of dry-rot commenced just at or a little above the top of the open fire scar, but rarely lower down. The avoidance of the dried-out wood around an open fire scar by the mycelium of this fungus is not at all in keeping with the results of experiments of Münch (19, 20, 21), which emphasized the highly favorable influence of an increase in oxygen coupled with a decrease in moisture in the host tissues on the development of various wood-inhabiting fungi. There should certainly be a big increase in the oxygen content of heartwood directly exposed to the air over that protected by a heavy layer of bark and sapwood, thus, according to Münch's theory, causing very serious dry-rot in the wood around open fire scars. The exact reverse of this is the condition actually existing. However, every wood-inhabiting fungus must have certain minimum physical requirements for its growth and development. Possibly the dried-out wood in this case falls below the minimum water requirement of *Polyporus amarus*, or it may be that certain chemical changes in the wood brought about by more or less exposure to the air inhibit the growth of the fungus mycelium.

Not every fire scar is inoculated, but the chances for inoculation with subsequent infection are rather high, owing to the relatively large area of heartwood exposed offering a broad surface for the lodgment of spores of the dry-rot fungus. On the optimum area, 70 per cent of the trees wounded by fire subsequently became infected,

on the intermediate area 64 per cent, and on the combined areas 67 per cent. The percentage of risk of a tree with a fire scar becoming infected is very high.

Next in importance to fire scars as a means of entrance for dry-rot come knots. Of the infections on the intermediate area 19 per cent entered in this way and 31 per cent on the optimum area, while for the areas combined the figure is 25 per cent, a little more than one-third as many as were traced to fire scars. The greater part of such infections, because they rarely extend beyond the wood of the knot itself, are of little or no importance as compared with fire scars in promoting serious cull. Of the total infections entering through knots only 48 per cent resulted in cull cases and 12 per cent in severe cull cases, while in infections through fire scars, 80 per cent of the total became cull cases and 38 per cent severe cull cases. The above data were at first tabulated by 40-year age classes, but this brought out nothing of importance. In the case of infections through fire scars most of them developed into cull cases in every age class; while for infections through knots up to 200 years less than half developed into cull cases, but beyond that age the cull cases became more numerous.

Considering all the severe cull cases as 100 per cent, it is found that fire is responsible for 84 per cent, knots for 10 per cent, and all other causes for the remaining 6 per cent. Furthermore, 81 per cent of the total volume of cull caused by dry-rot resulted from infections entering through fire scars. This demonstrates the serious rôle played by fire in connection with dry-rot. Fire scars are responsible for by far the greater number of infections, and a high percentage of these infections results in severe cull cases.

Knots are of some importance, though, in promoting severe cull cases throughout the life of the trees, even in the younger age classes. For example, of the fourteen severe cull cases occurring in all the trees up to 165 years of age, four entered through knots.

Of course, every tree is exposed to infection in this way throughout all except the very earliest years of its life, not only at one but at several points, since each tree usually has from several to many open knots or branch stubs, whose dead wood offers a bridge for the fungus from the outside through the bark and living sapwood into the heartwood. However, each knot presents only a very small surface for the lodgment of spores of heartwood-destroying fungi. Out of the total number of trees open to inoculation through knots on the optimum area only 18.2 per cent became infected in this way, on the intermediate area only 11.4 per cent, and for all combined just 15 per cent. In other words, in the trees studied the chances for a tree becoming infected with dry-rot through branch stubs were merely 15 out of 100.

An examination of knots on the outside of a log or tree usually does not give any reliable indication of the condition of the heartwood with respect to its degree of soundness. In this respect dry-rot differs markedly from the stringy brown-rot (*Echinodontium tinctorium*) in white fir and the ring scale or red-rot (*Trametes pini*) in Douglas fir.

Fire and knots are responsible for over 90 per cent of the infections and severe cull cases; other factors are of minor importance.

About 3 per cent of the infections on the combined areas entered through wounds the causes of which it was impossible to exactly determine. Some of these may have been fire wounds, others lightning. Of all such wounds 23 per cent subsequently became infected.

Lightning is of little importance as a means of entrance for dry-rot. On the intermediate area only 2.5 per cent of the infections are traced to this source, on the optimum area 1.5 per cent, and for the combined areas 2 per cent. As a rule, lightning causes small superficial scars offering little opportunity for inoculation, but at times large areas of the cambium and bark are killed. This dead bark then drops off, exposing the sapwood, which dries out. Cracks opening up into the heartwood are formed, and such large areas offer a good chance for the lodgment of fungous spores. This condition is reflected in the percentage of risk of inoculation when it is found that 19.2 per cent of the lightning-struck trees on the optimum area, 31.8 per cent on the intermediate area, and 25 per cent for the combined areas were infected by dry-rot through lightning wounds. This figure is higher than that for all other factors except fire. The chief reason, then, that lightning wounds are of so little importance in relation to decay is not that the character of wounding on the whole is such as to offer little opportunity for inoculation, but rather that this type of wounding is rare.

As an actual means of entrance of decay, frost cracks are even less important than lightning wounds. These cracks, while often of considerable length, even then present only a very narrow opening exposed to the air, the chances of fungous spores lodging in such a small opening being exceedingly small. Not quite 1 per cent of the infections for the combined areas entered through frost cracks, while the risk of infection is only 10.4 per cent lower than for all others except broken and dead tops. But though a rare source of infection, frost cracks sometimes carry an infection, entering through some other type of wound, over a greater linear extent in the heartwood than might normally be expected, thus resulting in a large proportion of cull. The pockets of dry-rot do not occur in the wood immediately adjacent to the cleft or crack, but are usually found some distance removed, leaving the wood around the crack sound.

This is because of the avoidance by the fungus mycelium of the wood around open fire scars.

Infections through broken or dead tops may be absolutely disregarded, both numerically and in respect to the resulting decay. Out of the 75 trees with these injuries only one infection occurred, and this resulted in a negligible amount of decay.

However, the true relation of these various types of mechanical injuries to one another in respect to their importance as a means for the entrance and development of dry-rot on the areas studied is not expressed by the percentage of the total infections for which each type of injury is responsible, but must be shown by the relation of the number of trees infected through each type of wound to the total number of trees both sound and infected. The figures in Table XI express this relation, which might be termed "percentage of risk of infection." In one set of figures is expressed, then, for the trees actually studied the numerical relation of the various types of injuries combined with the relative chances for inoculation offered by each. All the areas are combined.

TABLE XI.—*Risk of infection of incense-cedar trees with dry-rot entering through wounds of the various types.*

Cause of wounding.	Risk of infection (per cent).	Cause of wounding.	Risk of infection (per cent).
Fire.....	40.0	Lightning.....	1.2
Knots.....	15.8	Frost.....	.5
Unknown.....	1.6	Broken or dead tops.....	.1

The figure 40 for fire expresses the fact that of all the trees analyzed each tree had 40 chances out of 100 of being wounded by fire and subsequently becoming infected with dry-rot through this wound, and so on for the other types of injury.

The far greater importance of fire wounds as a means of entrance for dry-rot as compared with all other injuries is strikingly brought out. Knots, the nearest competitor, are far less important, while all the others practically can be neglected.

The close relation of wounds and infections is shown even better in figure 3. The curve for wounds is plotted from Table IX, knots, of course, not being included, for had this been done the wound curve would have followed the 100 per cent ordinate throughout all the ages. The curves for infections and cull are the same as those given in figure 2.

These curves show that infections are practically a function of wounds, the two curves having almost the same form, but of course the infection curve being lower throughout until both have attained 100 per cent. The curve for the percentage of cull is included in

order to emphasize the fact that while the increase in the number of wounds is closely followed by an increase in infections, the increase in the amount of cull due to decay is not a direct function of the increase in infections, but is also dependent upon the factor of age and thrift, as previously explained.

Meinecke (16, pp. 47-48) found in white fir that a combination of suppression and severe wounding was a prerequisite for serious decay in trees up to the age of 150 years. This does not hold for incense cedar. Of the ten severe cull cases in suppressed trees up to the age of 165 years, five occurred in trees slightly wounded, one in an entirely unwounded individual, and only four on severely wounded trees. Of the four dominant trees below the same age with severe cull cases, two are severely wounded and two slightly

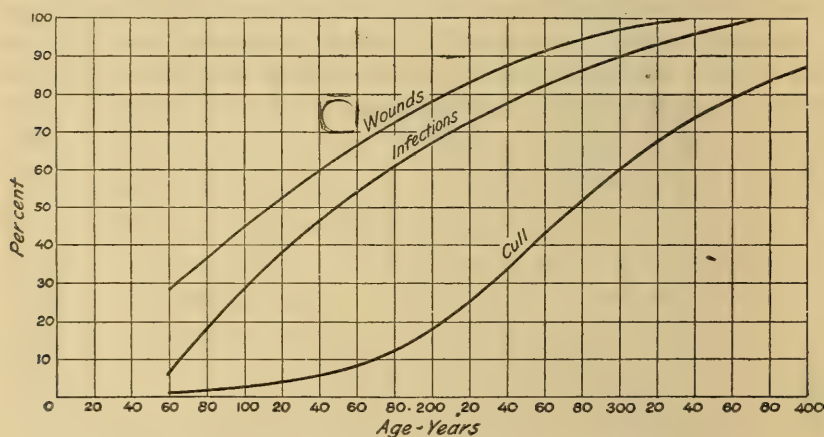


FIG. 3.—Relation of the age of incense-cedar trees to wounds, infections, and cull.

wounded. And, in fact, throughout all the age classes occur trees slightly wounded but with severe cull cases.

The foregoing considerations lead to the following conclusions: (1) Fire is responsible for by far the greatest number of dry-rot infections, commonly leading to serious decay, resulting in heavy cull. Fire is three times as important as its closest competitor, knots. (2) Knots are responsible for some far-reaching decay, but most of the infections through knots are confined to the immediate vicinity of the knot. (3) Aside from fire and knots all other means of entrance for decay are of little import. Lightning would be serious except that wounding from this source is rare. Frost is of no importance in promoting inoculation, since the wounded surface presented is small and frost cracks are relatively few. However, frost cracks often assist in carrying the dry-rot over a greater length of the bole than would be normal. Damage from unknown causes leads to some infection, but it is not of much importance. Infections

through dead or broken tops are so insignificant that they may be entirely disregarded. (4) Severe wounding is not a prerequisite for severe cull cases or extensive decay at any stage in the life of incense cedar.

APPLICATION OF RESULTS.

RELATIVE IMPORTANCE OF DRY-ROT.

In the foregoing discussion the one big factor which stands out almost to the exclusion of all others is the dry-rot. Mechanical injuries of certain types play some rôle, not only in destroying merchantable timber values but in lessening the annual increment. However, it is chiefly the fact that wounds are the means for the entrance of dry-rot which makes them of any but insignificant importance.

Factors reducing the annual increment of the host, namely, *Gymnosporangium blasdaleanum*, *Phoradendron juniperinum libocedri*, *Stigmatea sequoiae*, and *Herpotrichia nigra* are of minor importance. In fact, only the first two named, being decidedly ubiquitous, are worthy of the least consideration; but the resulting loss is so slight and intangible that under present conditions it may well be disregarded except incidentally. The rare trifling loss in merchantable timber from burls of the mistletoe can not be of consequence.

Fungi such as *Polystictus abietinus*, *P. versicolor*, *Polyporus volvatius*, and others (see p. 4), only attacking dead wood and never found on living trees, are to be regarded as beneficial, since they hasten the decomposition of ground litter, thus increasing the humus in the soil and removing a serious fire menace.

Loss resulting in the heartwood of living trees from the so-called secondary rots is very slight in the aggregate. It is rare that such decays are at all far-reaching, and, furthermore, it is possible that certain of them may be abnormal forms of the dry-rot.

To repeat, then, the one big consideration from a pathological viewpoint which must hold above all in the silvicultural treatment and utilization of incense cedar is the dry-rot, together with the interrelated mechanical injuries.

CONTROL OF DRY-ROT.

Very little can be hoped for in the line of any serious consideration or attempt at direct control of dry-rot on private holdings for years to come. The private owner is averse to any increase in expenditures which does not show prospects of immediate gain. On certain private holdings where the incense cedar was heavily affected by dry-rot, all the trees have been left standing, only the more valuable species being removed, leaving the diseased individuals to continue spreading the decay to uninfected members of the present and future generations.

On the National Forests a great deal can be accomplished in the way of control of mechanical injuries resulting in wounds through which the dry-rot fungus can enter. As has been shown, fire is by far the most important factor in promoting dry-rot, with knots, the nearest competitor, of relatively far less importance both in regard to the number and seriousness of resulting infections.

Fire can be, in a great measure, directly controlled. The ever-increasing efficiency of the fire-protection methods on the National Forests, with the continual reduction in the number of damaging fires, speaks for itself. Certain private holdings are also protected from fire, either incidentally by falling within the boundaries of a National Forest or through a protection system handled on a cooperative basis by the United States Forest Service. Knots, of course, can not be controlled. Natural pruning, with the continual production of dead branches, which later break off, is inevitable in any forest. However, it may be expected that infections through this source will become increasingly fewer as time goes on, in proportion to the reduction in the number of fire-wounded trees. All other factors, whether controllable or uncontrollable, and this includes frost and lightning, are of so little importance that they may be neglected in any consideration of mechanical injuries in the future stand.

But fire protection works for the future welfare of the stand alone. It can not affect the huge number of individuals in the forest with healed or open wounds through which dry-rot has already entered or those uninfected individuals with open wounds still exposing them to attack by heartwood-destroying fungi; nor can it have any influence on all the other injured, diseased, or distorted members of the forest community. These have no place in the stand, are in most cases a direct menace to the sound trees, and should be removed as soon as possible. Unfortunately, we have not been able to attain the highly desirable intensive practice of eradicating such undesirable individuals by means of improvement thinnings applied at will wherever needed in the forest.

Under present conditions this can only be done in the main through timber sales, with free-use permits playing a limited part. But the Government is far from able to sell the timber where cutting is most needed from a silvicultural point of view. Economic factors, especially transportation, and in some cases the degree of soundness of the stand play the chief rôle in determining the exact location of a sale area. In fact, a mature or overmature stand badly in need of cutting may have to be left untouched, owing to the refusal of prospective purchasers to handle the high representation of inferior species.

In the case of incense cedar, this prejudice on the part of the lumberman does not arise from any inherent qualities or characteristics

of the timber itself, but from the heavy infection of dry-rot in the mature and overmature trees, with the resulting high percentage of cull. Sound incense cedar is distinctly of high value and much sought after for special purposes, such as pencil slats, and in a lesser degree for cabinet material and interior finish. Wood not too badly decayed is of some value for posts and low-grade railroad ties. But the lumberman is naturally averse to handling a large quantity of unmerchantable material in order to secure a small percentage of a really valuable product.

The first step in overcoming this objection must be the application of a careful scaling policy.

SCALING.

In order to handle incense cedar properly on a timber sale the outward indications of hidden defect should be thoroughly understood. A valuable index to the condition of the timber will be found in the presence of sporophores or shot-hole cups on the trees. When found, their apparent age should be carefully taken into account in determining the degree and extent of the dry-rot (see p. 10). Excellent clues as to how a decayed tree should best be bucked are contained in the occurrence of shot-hole cups or sporophores. Since heavy dry-rot almost invariably extends from the ground level to a varying height above the highest sporophore or shot-hole cup it would, of course, be a waste of labor to buck the tree again at any place between the stump height and the last-named point.

The scaler should keep in mind the relation of wounds, particularly those caused by fire, to dry-rot in the tree. A large pocket of dry-rot occurring close to a healed wound, especially fire scars in the butt of the tree, usually diminishes in area as the height increases and ends in a point immediately above the termination of the healed fire scar it is following. For example, in case a butt log shows a large pocket of decay adjacent to a healed fire scar on its basal cross section, while the top cross section is absolutely sound, it is safe to assume that the decay will end about 6 feet from the base of the log, or in exceptional cases a length of 10 feet may be attained (see p. 44).

Particular care should be used in scaling butt logs with an open fire scar at the base. As has been shown (see p. 44), dry-rot of any seriousness is rarely found in the dried-out wood around an open fire scar. The base of such a log is nearly always absolutely sound; the top may show the entire heartwood unmerchantable. It is quite possible, then, for the scaler to judge the decay as extending half way down the log from the top, giving the lower half full scale and judging the upper half unmerchantable. This procedure is

particularly likely to be followed on double-length logs (20, 24, 28 feet, etc.). But invariably the dry-rot will commence just at the top of the fire scar and almost immediately spreads out over the entire radius of the heartwood. In other words, in a log with an open fire scar showing on the base but otherwise sound and with pockets of dry-rot in the top end, the decay should be considered as beginning at about the top of the fire scar and extending from there to the upper end of the log in practically the same degree and radial extent with relation to the heartwood as is shown on the top end.

Advance rot (see p. 13) should be treated just the same as mature dry-rot.

In the case of a large swelling on the bole caused by mistletoe it is best to have the tree bucked in such a manner as to exclude the swelling rather than have such a defect reach the landing as part of an otherwise sound log and then be scaled out.

MARKING.

Timber sales at present offer the only extensive means of practicing intensive silviculture on our National Forests, and the entire results are absolutely based on correct marking. Fundamentally, the object of marking is to leave the stand in the optimum condition for its future welfare and development. This goal should never be lost sight of, no matter how clouded the issue may be by a complexity of immediate and often pressing considerations. To attain this end requires a high degree of skill, grounded on a thorough understanding of all the factors involved, not the least of which are those making for total loss in the species under consideration.

The fundamental object of marking has been far from completely attained if, after cutting, diseased individuals are left standing to carry infection to otherwise sound trees of merchantable size, besides menacing the future of the advance growth and reproduction. Obviously, then, trees with sporophores or shot-hole cups should invariably be marked for cutting, for these are positive proofs of damaging dry-rot. Such trees are as a rule not only a total loss, being unmerchantable from the butt to varying distances of 10 to 50 feet above the highest sporophore or shot-hole cup, but are the most potent factors in spreading infection to other trees, since infection can only be brought about by spores coming from sporophores on diseased trees. True enough, shot-hole cups in themselves do not menace surrounding trees with possible infection, but they do indicate that the fungus has reached fruiting maturity and is very likely to develop more sporophores, as is attested by the not uncommon occurrence of two or more shot-hole cups of varying ages on the same tree. Furthermore, the fungus mycelium in any in-

fectured tree possesses the potential capacity of sooner or later producing sporophores.

Remembering the great percentage of dry-rot infections entering through wounds, trees with injuries must be treated accordingly. Trees with healed wounds are of less concern than those with open wounds, since the former, if not already infected, are immune except for the inevitable, though fortunately not frequent, attack through branch stubs, while the latter are still open to infection. Then, too, the area of heartwood exposed by the injury is of grave consequence; the larger the area the greater the opportunity for infection. We already know the high percentage of infections through fire scars which so commonly expose large areas of heartwood; therefore fire-scarred trees, above all, should be marked as heavily as possible. Large lightning wounds are a serious danger, but small superficial injuries, especially if high up on the bole, can be almost disregarded. Frost cracks, though by virtue of the exceedingly small amount of heartwood they expose offering slight chance for infection, often aid in spreading infection established through some other agency, and trees with such wounds should be marked for cutting whenever possible. From the pathological viewpoint spiketops or stagheads may be almost disregarded except for their suppressing influence on the injured individual, but sound silviculture demands the removal of such trees from the stand.

Even if the Utopian dream of a forest community without injured individuals could be attained, this in itself would not result in completely controlling the destruction wrought by the dry-rot fungus, but only in minimizing it in a great measure. There would still be some loss from infections entering through knots. Then, too, no matter to what degree of intensive management a forest in this region may be brought in the future, some injuries will always occur, even from fire, while frost and lightning wounds are inevitable. The unavoidable injuries to a certain number of the seed trees during logging on any sales area must not be overlooked.

Therefore, all wounded trees must not only be eliminated on sales areas, but trees, even though unwounded and thrifty, must not be left with the expectation that they will be sound at the next cutting if by the time the cutting takes place they will have attained or passed beyond the age at which loss from dry-rot becomes of serious economic importance. It has been shown that the critical age occurs at 165 years and the age of decline at 210 years. Beyond the age of 165 years suppressed trees become subject to extensive decay, while up to that age they may be expected, with rare exceptions, to remain relatively sound, the same being true for the dominant trees at an age of 210 years.

Since in the intermediate range all but an insignificant percentage of the trees are suppressed in a greater or less degree, it becomes obvious that in this region incense cedar should be cut by the time it reaches 165 years, the critical age.

In the optimum range, suppressed trees must not be allowed to pass 165 years and dominant individuals 210 years (the age of decline) before felling.

Even in the distant future, when the risk of wounding in the forests is reduced to a minimum, it is highly problematical whether a new age of decline can be established at a higher age, on account of the entrance of decay through knots. Damaging dry-rot has entered trees through knots beginning at 105 years, and while such cases are rare in the years below the critical age and age of decline, yet they are sufficient to indicate that this condition will always have to be reckoned with. Furthermore, as time goes on, the increasing value of timber will result in noticeably lowering figures as to what constitutes an allowable percentage of cull in any species.

From a pathological viewpoint the critical age must limit the rotation of incense cedar in the intermediate range. It is doubtful whether even in the managed stands of the future the incense cedars in this range will be other than suppressed in most cases, since the present widespread suppression does not seem to be the result of any influence that could be removed by a system of forest management, arising apparently from the fact that the cedar is removed from the region of its optimum development.

In the optimum range the rotation must be limited by the age of decline. The critical age is not so important except during the period of transition, for suppressed trees, while common enough in the virgin stands of to-day in this range, will have little place in the managed stands of the future. Here, the species being in its optimum, nothing but thrifty, dominant individuals should be produced under a rational system of management.

The influence of decay on harvesting a timber crop was hinted at years ago by Von Schrenk (27, p. 203) and clearly pointed out by Meinecke (16, p. 61) for white fir. Mitchell (17, p. 32) took this so-called pathological rotation carefully into account, recommending a rotation of 150 years, at which time the species attains a good merchantable size. The rotation recommended by Mitchell is based on Meinecke's preliminary study of dry-rot.

As a result of the present study, the pathological rotation for incense cedar must be placed at 165 years in the intermediate and 210 years in the optimum range. During the transition period, while suppressed trees are still a factor in the optimum range, these should be cut when not older than 165 years. This does not mean that in the two regions under consideration cedar can best be cut at regular

intervals of 165 and 210 years, respectively, but simply that if it is left to a greater age there is a full realization of the resulting enormously increased loss through dry-rot. The pathological rotation becomes a maximum limiting factor for the actual rotation, which may be financial, silvicultural, or one of maximum volume, depending on conditions in the future. From present indications it is highly probable that all other rotations for incense cedar will fall below the pathological rotation in both regions; the difference will be quite marked in the optimum range. It is possible in the optimum range that during the transition period, if necessary to leave suppressed trees standing after cutting, the increased vigor of such individuals which may follow the opening up of the stand might raise the critical age somewhat, but in the present state of our knowledge not only regarding the influence of thinning on the development of wood-destroying fungi in standing trees, but in the case of incense cedar regarding the actual response of the trees themselves, this consideration is entirely too hypothetical to influence our present conclusions.

SUMMARY.

The results of this study point to the following main conclusions:

(1) Incense cedar is classed as an inferior species because of a uniformly heavy percentage of cull caused by the dry-rot fungus (*Polyporus amarus*). Judicious scaling and instruction in the proper methods of bucking will ultimately aid materially in changing this view.

(2) Dry-rot can be eliminated in a large measure from future stands by intensive fire protection, but it can not be entirely controlled in this way, owing to the continued occurrence of unavoidable mechanical injuries caused by pruning, lightning, and frost.

(3) The following directions should apply to marking on timber sales:

(a) Trees with sporophores and shot-hole cups must be marked for cutting.

(b) Seriously wounded trees, especially those with fire scars, should be marked to be cut.

(c) In the intermediate range all but a very small percentage of the trees are suppressed. Since suppressed trees are subject to severe dry-rot after they pass the critical age of 165 years, trees left standing should be of such an age that they will not pass that age before the next cutting occurs. Dominant trees, being so few, may be classed with suppressed trees, but in reserving seed trees only the most thrifty individuals should be considered. By this practice some dominants will be among the trees left, and these will be safe until the age of 210 years is reached.

(d) In the optimum range, suppressed trees are subject to damaging dry-rot after they pass the age of 165 years (the critical age), while dominant trees are safe until 210 years (the age of decline) is reached. Therefore, suppressed trees left standing must be of such an age that they will not pass the critical age (165 years) before the next cutting occurs, and dominant trees left should not pass the age of decline (210 years) before the next cutting. Suppressed trees, however, should be heavily marked for cutting and only left unmarked if unavoidable.

(4) The rotation for incense cedar must not exceed 165 years in the intermediate and 210 years in the optimum range.

If for any reason the pathological rotations, as determined in this paper, must be exceeded in future operations on cut-over lands, the forester in making the decision will have a full realization of the enormous loss in merchantable timber to be faced through cumulative risk of cull due to dry-rot in the stands so handled.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 872

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



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INSECT CONTROL IN FLOUR MILLS.

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MILL INSECT CONDITIONS BETTERED.

The control of insect pests in flour and cereal mills has become a very important feature of food conservation and of mill construction and operation. The cleanliness of many of the well-lighted, concrete mills, such as are being built more frequently now than ever before, and their comparative freedom from pests, are emphasized by the conditions that exist in old-type structures. These latter offer insects every advantage in their fight against the miller. It is true that many of these older mills are established in rambling, loosely constructed buildings that can be neither properly cleaned, from the standpoint of insect destruction, nor made tight for the application of successful control measures. Fortunately the losses caused by insects to the mill owners and the advantages of modern construction are working hand in hand to bring about a constant change for the better. With modern equipment installed in buildings erected with a view to suppressing insects, more millers are joining the ranks of those who know that they can control insects and offer the public a product reasonably free from infestation.

INCENTIVE LEADING TO INSECT SANITATION.

Owners of flour mills are frequently blamed by brokers, retail grocers, and the public at large for insect infestations found in their products when these appear on the market or in the home. Sometimes the miller is to blame; often he is not. It is, however, within his

power, if he is the owner of a well-constructed mill, so to control pests that he can state, with honesty, that the product he places upon the market is reasonably free from insects, including their eggs, and that if infestation develops soon after his product has been warehoused or otherwise disposed of, the infestation is due to one or more of several known conditions for which he is in no way responsible.

There has persisted among many millers, as well as consumers, the belief that the egg or "germ" of insects is within the grain at the time it enters the mill and that it goes uninjured through the milling process to lie dormant in the finished product until such time as conditions of warmth and moisture favor its development. This belief rests upon a false foundation. The ordinary destructive insects that infest grain or flour or any cereal product lay eggs large enough to be readily seen by an experienced eye once they are separated from the host material. They are all so large that they can not pass through the meshes of No. 10 XX silk bolting cloth. Since this is true, even badly infested flour can be reprocessed and rendered absolutely free from pests if bolted through a No. 10 XX or finer cloth.

It is possible to produce flour entirely free from infestation as it comes from the bolting machines. If it is sacked in containers upon which no eggs have been laid or in which no larvæ are present, and is stored in a warehouse in which there is no infestation, it will leave the mill free of infestation. If such a product shows infestation by the time it reaches its destination, it has become infested while en route. To guarantee a product leaving the mill establishment as free from infestation is so entirely within the bounds of reason that one wonders whether certain millers should be permitted to ignore insect infestations and put upon the market supplies that are invariably infested.

MEDITERRANEAN FLOUR MOTH.¹

MEDITERRANEAN FLOUR MOTH MOST SERIOUS MILL PEST.

While there are many insects that may become troublesome in flour mills, it is the Mediterranean flour moth alone that seriously affects the operation of the mill and has brought with its advent from Europe into the mills of the United States losses that have forced millers to consider insect suppression. The weevils and other granary pests which are brought into mills with grain, and the flour beetles or "bran bugs" which become established in practically all mills sooner or later, will not be discussed in this bulletin, though they must be taken into consideration by millers. The remedial measures advocated for the suppression of the Mediterranean flour moth, with cleanliness, will hold these nonwebbing insects in check.

¹ *Ephestia kuehniella* Zell.

MEDITERRANEAN FLOUR MOTH AN INTRODUCED PEST.

The Mediterranean flour moth is a pest introduced into this country from Europe. Until 1877 it was little known in the Old World, but in that year it was discovered in a flour mill in Germany. Later it spread to Belgium and Holland, and in 1886 was found in England. In 1889 it was found in destructive numbers in Canada. The Mediterranean flour moth first appeared in the United States in 1892, when it was found infesting flour mills in California. Since that time its spread has been fairly rapid. It was found established in New York and Pennsylvania in 1895, in Minnesota in 1898, in Wisconsin in 1900, and in Michigan in 1902. By 1904 it was reported from other States, including Indiana, Illinois, Montana, Colorado, Ohio, and Iowa. Since 1904 its spread has been very rapid, until at the present time the Mediterranean flour moth is present in practically every milling center and may be found in warehouses throughout the country where flour and cereal products are stored.

LOSSES DUE TO INFESTATION.

Millers have reason to dread this pest, since the webbing habit or the larvæ sometimes completely stops the machinery and always, sooner or later, necessitates the expenditure of time and money to keep the pest under control. It is difficult to obtain definite estimates of losses caused by the Mediterranean flour moth, but for mills of 1,000 barrels capacity it is seldom less than \$100 to \$200 a year. The average loss, according to Dr. F. H. Chittenden, "due to closing down the mill and cost of treatment seems to be not far from \$500 for each fumigation, 'to say nothing of the loss to business,' according to one Kansas milling firm. An estimate of \$1,000 for two fumigations would not be far from right, although others estimate \$2,000, and still others—owners of larger mills—claim it to be \$5,000 a year." Prof. G. A. Dean has stated that the loss to Kansas grain and mill interests may be placed very reasonably at "not less than \$2,000,000 annually." It is evident that the loss to flour and cereal mill owners throughout the country is enormous and far beyond the average belief.

TRANSFORMATIONS OF THE MEDITERRANEAN FLOUR MOTH.

The adults of the Mediterranean flour moth are moths or millers with a winged expanse of a little less than 1 inch. The forewings are pale leaden gray with black markings, as shown in figures 1 and 2, although sometimes the wings are much darker. These parent moths are very tame, and when resting quietly upon various portions of the mill and stocks assume a peculiar attitude, illustrated

in figures 1, *b*, and 2. The female moth lays eggs in accumulations of flour, up and down elevator legs, throughout spouts, around dust collectors, in bolters, purifiers, etc. From these eggs hatch the larvæ or worms. When full grown, the larvæ are about half an inch long and are whitish or pinkish in color, with minute black dots and fine hairs, as shown in figure 1, *c*, *e*. When full grown the larvæ spin cocoons in which they transform into the reddish brown pupæ shown in figure 1, *d*. From these pupæ emerge the parent moths of the next generation.

LENGTH OF LIFE FROM EGG TO ADULT.

Dean² states that when the temperature ranges from 85° to 90° F., the eggs of the moth hatch in about 3 days, the larvæ become full grown in about 40 days, and the pupal stage requires from 8 to 12 days

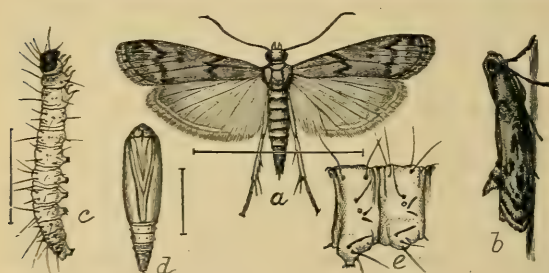


FIG. 1.—Mediterranean flour moth: *a*, Moth; *b*, same from side, resting; *c*, larva; *d*, pupa; *e*, abdominal segments of larva. The hair lines by *a*, *c*, and *d* represent the actual length of the forms. (Chittenden.)

more. Under ordinary flour-mill conditions about 9 weeks are required for the pest to pass through its life cycle from egg to adult. Length of the life cycle varies greatly with the temperature. At temperatures lower than 55° F. activity is suspended. During most favorable temperature conditions, 24 days has been found by Chittenden³ to be the minimum required for larval development.

LARVAL HABITS MAKE MOTH MOST SERIOUS PEST.

The Mediterranean flour moth is the most serious of all mill pests, not so much because of the food values it actually consumes, but because the larvæ or worms construct in the flour silken tubes in which they live, spin a fine silken thread wherever they crawl, and spin cocoons in and about the machinery and stock. As they grow older they spin increasing amounts of silk until, when they are full grown, the quantity of web they spin in crawling about machinery, sacks, etc., in search of a suitable place to spin cocoons is enormous, and causes a bad webbing or matting of the flour. These masses of webbed flour receive during the operation of the mill fresh layers of flour, which

² DEAN, G. A., MILL AND STORED-GRAIN INSECTS. Kans. State Agr. Coll. Exp. Sta. Bul. 189, p. 226-227. July, 1913.

³ CHITTENDEN, F. H., THE DEVELOPMENT OF THE MEDITERRANEAN FLOUR MOTH. In U. S. Dept. Agr. Div. Ent. Bul. 6 (n. s.), p. 85-88, 1896.

in turn are matted together by the burrowing and crawling larvæ. Finally the webbed masses (fig. 3) become so large that they choke or clog the machinery and force the miller to shut down. There is then nothing left for the miller to do but set his men to a thorough cleaning out of all machinery, spouts, etc.

HOW MILLS BECOME INFESTED.

The Mediterranean flour moth gains access to the majority of mills through the medium of secondhand or returned sacks. The moths occur in blending plants, where they lay eggs on old sacks, and the lar-

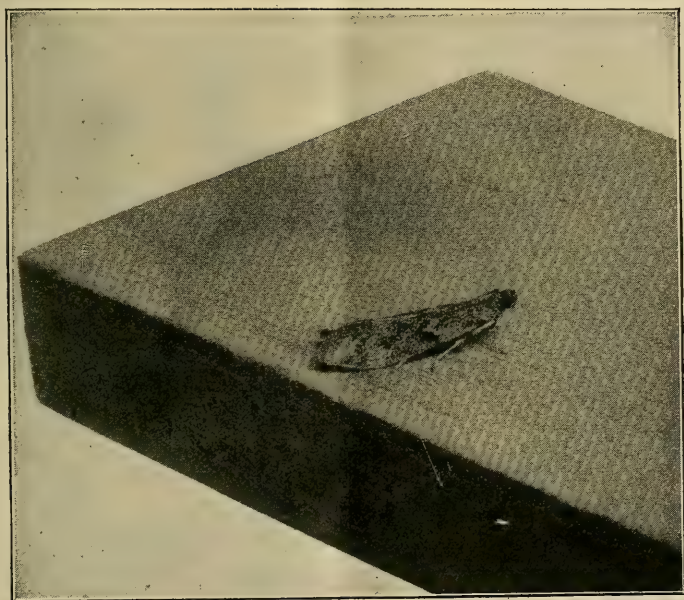


FIG. 2.—An adult Mediterranean flour moth resting naturally upon a plank. Notice characteristic posture. These moths are so tame and remain so quiet that they often escape attention. (Dean.)

væ then hide and spin cocoons in the seams and folds, thus making it easy for the pest to be carried from place to place. The installing of secondhand machinery that has not been properly fumigated is also a means of dissemination. These are the main avenues of entry to uninfested and new mills that any miller can close if he will. The miller is, however, more or less helpless to prevent infestations when his mill is located in a center of general infestation, as the adult moth can fly from building to building. Of course, all returned sacks are apt to bring infestations.

WHERE TO LOOK FOR EARLY INFESTATIONS.

Millers who fear that the Mediterranean flour moth will become established in their mills and wish to apply remedial measures as

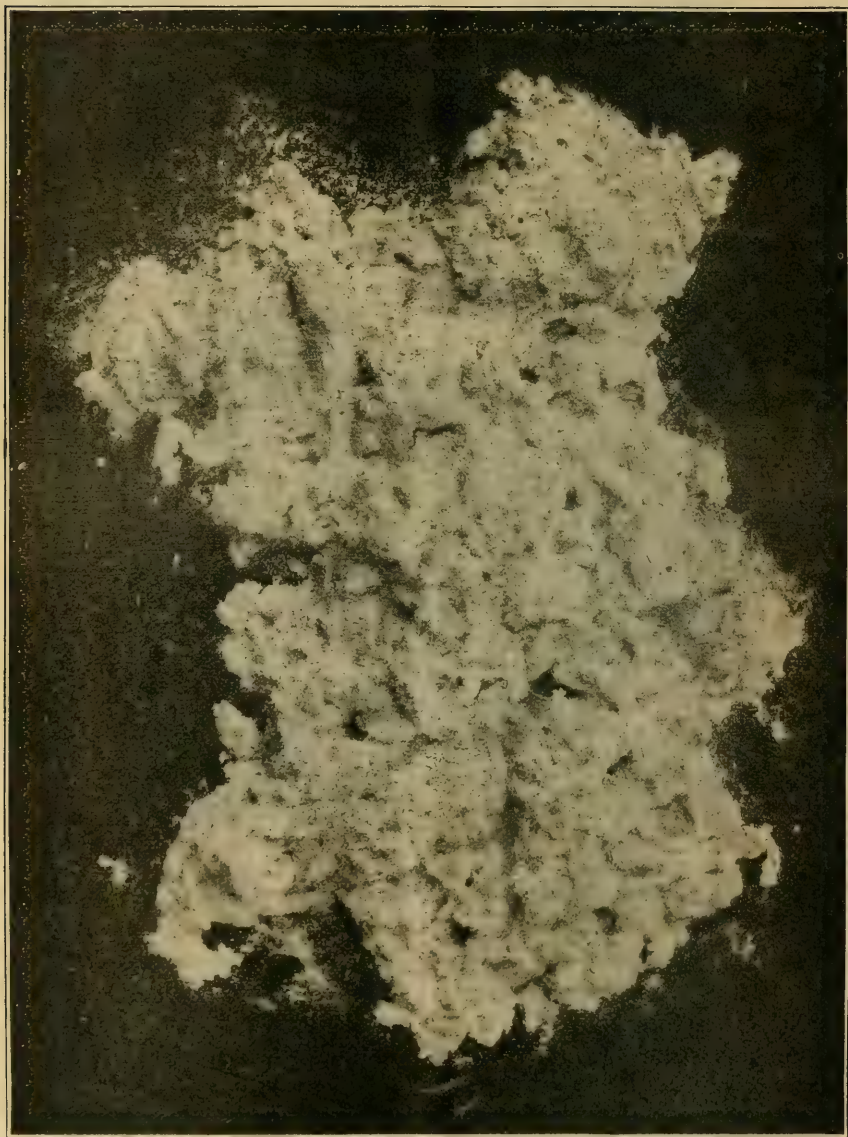


FIG. 3.—A clump of matted flour showing result of the webbing habit of the larvæ of the Mediterranean flour moth. (Chittenden.)

early as possible should keep an especially close watch for the pest in places where it is apt to appear first. These are in elevators, purifiers, and the machinery carrying and handling the warm sweet

or germ stocks. During the cooler months the pest is often found in and about the dust collectors, especially if these are warm or are taking heat from the rollers. It should be taken for granted that returned or secondhand sacks are infested and must be treated before being taken into the mill proper. The moth is too widely distributed to-day to justify a miller in taking chances with these sacks.

METHODS OF CONTROL.

The control measures for the Mediterranean flour moth, and, incidentally, for other mill pests, may be divided into three classes: Preventive, including attention to cleanliness; natural control, dealing with nature's attempt at control by parasites; and artificial control, including destruction of pests by fumigation, heat, and cold.

PREVENTIVE MEASURES.

The need for cleanliness can not be overemphasized. Insects prefer to lay eggs upon and develop in flour and cereals lying in undisturbed darkened situations. Insects are most abundant in such places. The frequent cleaning out and destruction of such material nips in the bud what may become an infestation causing a loss many times greater than the cost of cleaning. Experienced millers know this.

FREQUENT CLEANING.

A large proportion of insect infestation in flour mills is due directly to lack of cleanliness. This does not mean that the product coming from such mills is unclean, but that flour is allowed to accumulate for long periods in various places throughout the machinery and buildings to serve as a rich breeding ground for pests, which multiply rapidly and spread to all parts of the mill. It has already been stated that under ordinary flour-mill conditions during the warmer months, the Mediterranean flour moth requires about nine weeks for each generation. Certain other mill pests require from 5 to 7 weeks to complete their life cycle. It is, therefore, evident that if mills are given a thorough cleaning about every five weeks throughout the summer months, much good will be accomplished in reducing pests, for in destroying the stocks removed from undisturbed or dead spaces, many insects are captured and destroyed also. Labor to brush out and remove accumulation of stocks from elevator boots and flour conveyors, and to destroy them by burning is labor well spent. Going over elevator legs with a spout maul, or the use of elevator and belt brushes (fig. 4), will dislodge much infested material and aid greatly in removing accumulations

GOOD CONSTRUCTION.

If walls and ceilings are smooth and well painted or whitewashed, they are kept clean more easily, and offer no places for flour to lodge or insects to breed. Rough stone or brick walls (fig. 5), or those made of matched boards (fig. 6) offer many hiding and breeding places. Floors should be of concrete, where this is possible, for board

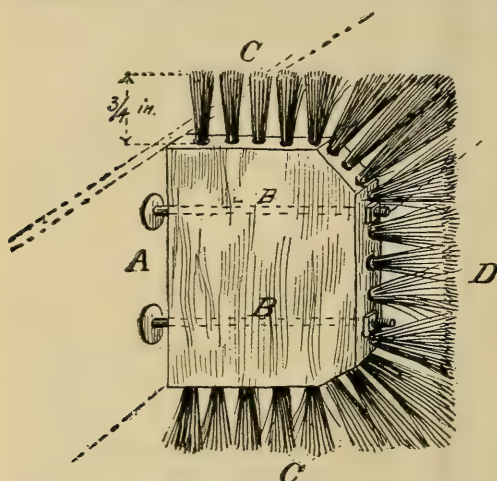


FIG. 4.—Elevator and belt brush for cleaning elevators infested by the Mediterranean flour moth. It is made by taking a piece of $1\frac{1}{2}$ -inch board of same dimensions as elevator cups, fastening bristles to three sides. Side A is fastened to elevator belt with flat-headed bolts running through board, as shown at BB, the bolts being $\frac{1}{4}$ or $\frac{3}{8}$ inch. Bristles on sides CC should be $\frac{3}{4}$ -inch long, but those at D should be longer, so that a good brushing to outside of elevator may be secured. Such a brush can be made to fit any elevator. (Chittenden.)

floorings offer shelter, unless unusually well constructed. Floors and walls should be so joined that there is no opportunity for accumulations along sides and corners. Well-cemented basements that are light and dry are an aid.

Machinery should be placed high enough to allow frequent and thorough cleaning beneath it. Where practicable the bottoms of flour conveyors should be of metal and rounded, so as to permit the least amount of flour or meal to accumulate along the side and at the ends. The hoppers of the rolls should be constructed of cement and in

such manner as to allow no flour to accumulate in inaccessible places.

USE OF LIME.

A liberal use of air-slaked lime in dark corners of damp basements will not only serve as a repellent to insects, but will also tend to destroy some of the objectionable odors and sweeten the air.

CARE OF SACKS AND BAGS.

New sacks and bags should not be stored in packing rooms or in any place where they become dusted with flour or cereal products, for in this flour dust various mill pests can breed and become established ready to attack stocks packed in the sacks. This is an important point often overlooked. Secondhand sacks should never

be taken into the main mill building before they are thoroughly disinfected. It has already been stated that in the majority of cases the spread of moths from mill to mill is traceable directly to the use of untreated secondhand sacks. Such sacks should be stored in a

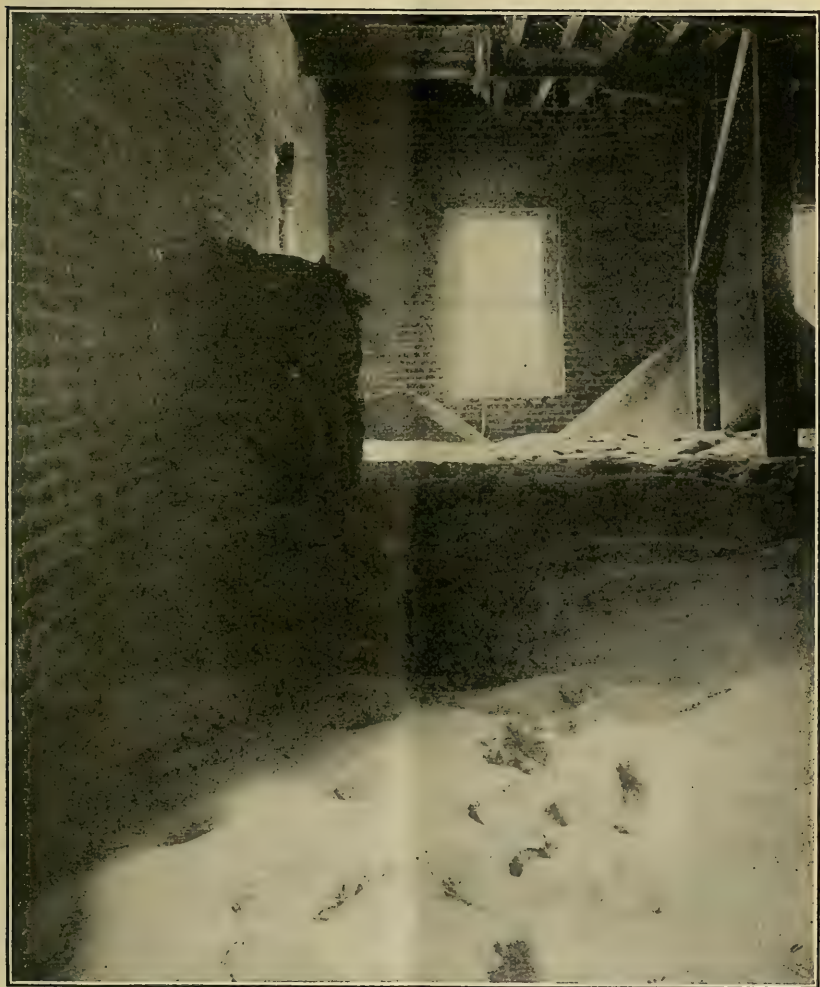


FIG. 5.—View in basement of flour mill. Note accumulations of webbed flour on floor, on bundles of twine, clinging to brick walls, and hanging from overhead beams. The flour in the foreground on floor is badly webbed. Such conditions are not allowed to exist where control measures are put into successful operation.

small, tightly constructed house separated from any part of the mill, and there treated either by heat or fumigation. This may involve extra handling but should become a part of the routine of protection against pests.

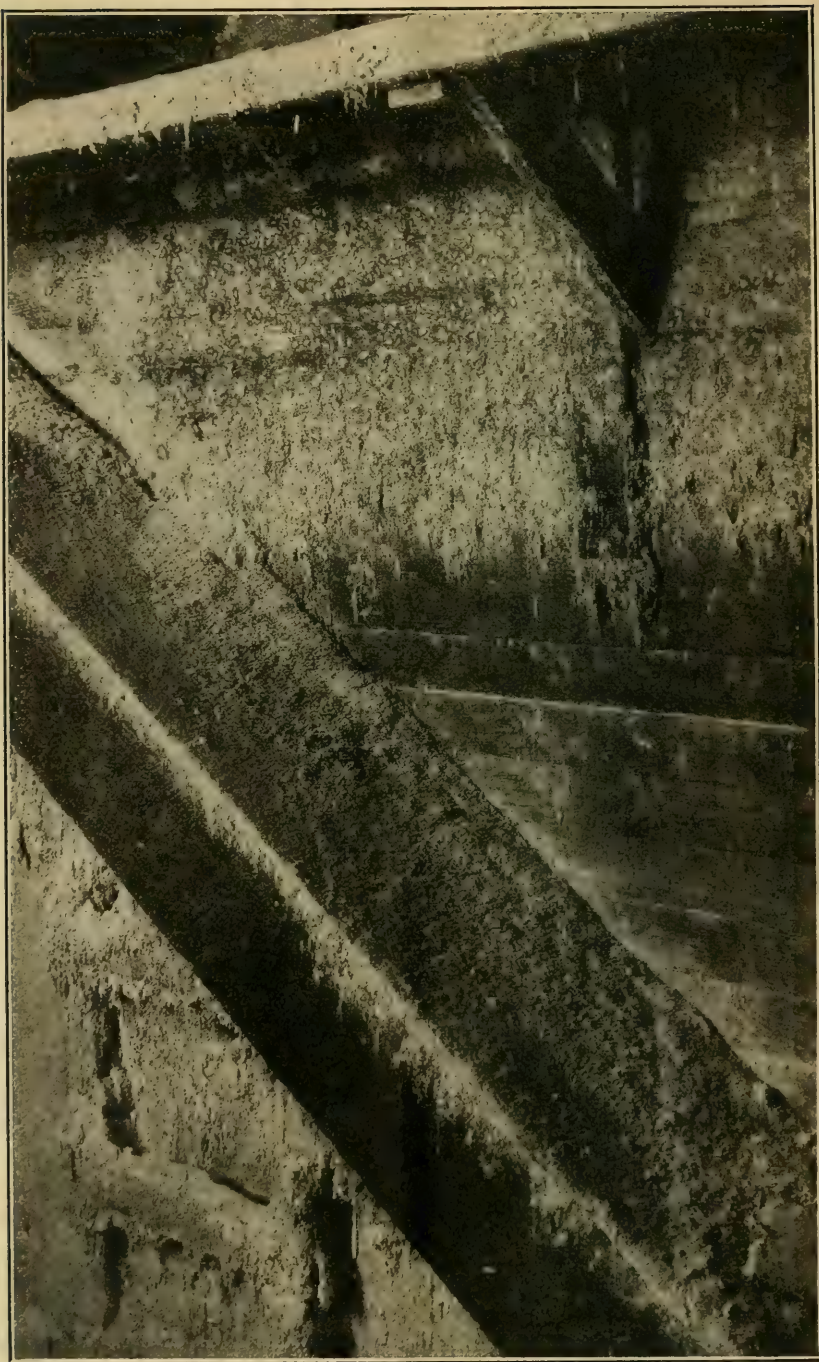


FIG. 6.—Portion of side of very poorly kept flour mill. Note accumulations of flour, much of which is webbed by the flour moth, on side walls, timbers, and ladder. Such neglect breeds trouble.

CLEANLINESS IN WAREHOUSE ROOMS.

Warehouse rooms, as well as the mill proper, should be kept as clean as possible. After each movement of stocks the floor and walls should be cleaned to prevent insects present from holding over to attack a new stock. Neglect of this simple precautionary measure has resulted in a more rapid infestation of warehouse stocks than is generally appreciated.

NATURAL CONTROL BY PARASITES.

In many mills the Mediterranean flour moth is attacked by insect parasites, *Habrobracon hebetor* (Say) and *Omorga frumentaria* (Rond.), but in no case are these of sufficient importance to warrant a miller depending entirely upon them, although at times they may prove a valuable control factor. They are not a dependable factor in any part of the United States. In a successful fight against the flour moth, control by parasites should not be relied upon.

ARTIFICIAL CONTROL MEASURES.

Since the spread of the Mediterranean flour moth from Europe to the milling centers of the United States experimental work has been conducted to determine the most satisfactory methods of control. From the various processes advocated from time to time, such as fumigation with sulphur, carbon disulphid, tobacco fumes, formaldehyde gas, etc., there have finally emerged two control measures that have now proved their value. These are fumigation with hydrocyanic-acid gas and control by heat. Where these can be intelligently and thoroughly applied results can be guaranteed. Heat is unquestionably the cheapest and simplest agent of control now known. Millers have had varying results in attempts to control the moth with freezing temperatures.

HYDROCYANIC-ACID GAS TREATMENT.

Fumigation with hydrocyanic-acid gas, while effective, is a disagreeable method of control. The gas generated is deadly to man, as well as to insects, and precautions must be taken to safeguard the lives of laborers and dwellers in closely associated buildings. It is assumed for the purposes of this bulletin that no milling concern will attempt fumigation with hydrocyanic-acid gas without calling in the services of an expert familiar with the process.² It may be added that where it can be used, hydrocyanic-acid gas fumigation is perfectly safe when conducted under the immediate supervision of a

² For more complete information regarding the use of this gas, write to the U. S. Department of Agriculture for publications.

properly informed and careful person. Success in the use of hydrocyanic-acid gas is in proportion to the tightness of the mill to be fumigated. Many old loosely constructed mills can not be fumigated successfully, even by an expert fumigator, because they will not hold the gas sufficiently long. In such mills one can not hope to do more than reduce the moth temporarily by any one fumigation. In tight structures two thorough fumigations applied dur-

ing warm weather within a short time of each other, as discussed on page 27, have been known to exterminate the moth. In rare cases one fumigation has exterminated the moth.

PRECAUTIONARY MEASURES.

Although it has been stated above that no mill concern should attempt fumigation without the assistance of a chemist, entomologist, or other person well informed regarding the process, attention should be called to several precautions that must be taken to guard against fatalities arising from inexcusable carelessness and ignorance. Very few deaths have occurred as a result of fumigation with hydrocyanic-acid gas as a mill fumigant, and those that have occurred have been due to



FIG. 7.—Wooden oil barrel, well soaked with water previous to use in fumigation, set in galvanized iron washtub partially filled with water to which have been added several handfuls of sal soda.

criminal neglect on the part of those responsible for the fumigation.

Where mills are in buildings well isolated from other buildings, owners need not consider neighbors in their plan for fumigation, but when the fumigation is to be conducted in one of a series of buildings, such as occur in city blocks, owners of property immediately adjoining must be informed of the intention to fumigate and arrangements made with them whereby they will be ready to vacate their stores or offices should the fumes penetrate the intervening walls. The odor of hydrocyanic-acid gas is easily detected, and the person in charge of

fumigation should advise regarding the need to vacate. Persons should be advised not to remain in rooms closely associated with rooms being fumigated if the odor of the gas can be detected. In numerous fumigations persons have remained at their work even when the odor of the gas was very pronounced, and workmen have been known to carry on trucking operations in warehouses where the odor of the residual gas after fumigation was so strong as to give the writer of this bulletin unpleasant feelings. Rooms adjoining those being fumigated should be kept well ventilated, but even then, to remain in them when the odor of the gas can be detected may lead to fatalities directly chargeable to the fumigator. To attempt fumigation without the approval and cooperation of those controlling the occupants of adjoining buildings may lead to fatalities directly chargeable to criminal neglect on the part of the person conducting the fumigation.

Guards should be placed at entrances that can not be closed by means of reliable locks to thoughtless intruders. Only trusted men should be employed to assist in any process of fumigation, and this holds particularly true of the person or persons left on guard. One man, at least, is known to have been killed because he was not informed of the fumigation, returned for night work, and entered through an unlocked door left temporarily unguarded by a sleeping guard. A genuine responsibility rests upon a person conducting fumigation and he should discharge his duties with all seriousness. He should choose as helpers only the most intelligent and trustworthy employees.

PREPARATION OF MILL FOR FUMIGATION.

Preliminary cleaning.—In fumigating a mill the greatest loss of time is caused by the need for preliminary cleaning; the fumigation can be done between Saturday night and early Monday morning or within any period of 24 hours' duration. The reason for thorough cleaning and destruction of flour and accumulations from various parts of the mill is primarily to leave in the mill at the time of fumigation no masses of stocks which the gas must penetrate to reach all the insects. Hydrocyanic-acid gas, deadly as it is, can not be depended upon to reach and kill all moths, pupæ, eggs, and larvæ if these are buried beneath several inches of well-packed flour, such as often occurs in dead spaces of machines, in floor cracks, basements, etc. The removal and destruction by burning of such accumulations which, as has been stated already, are favored by pests as feeding and breeding places, destroy large numbers of insects, as well as leave the mill in a condition to be fumigated to best advantage.

Make mill as tight as possible.—The mill should be made as tight as possible, so that the gas generated can not escape before it has had a chance to kill the flour moth. Broken windows, ventilators,

and cracks about window frames can be made tight by pasting strips of paper over them. Even an occasional open window and doorways, stairways, and elevator shafts can be fairly well sealed by the use of heavy paper applied in several thicknesses by paper hangers. All

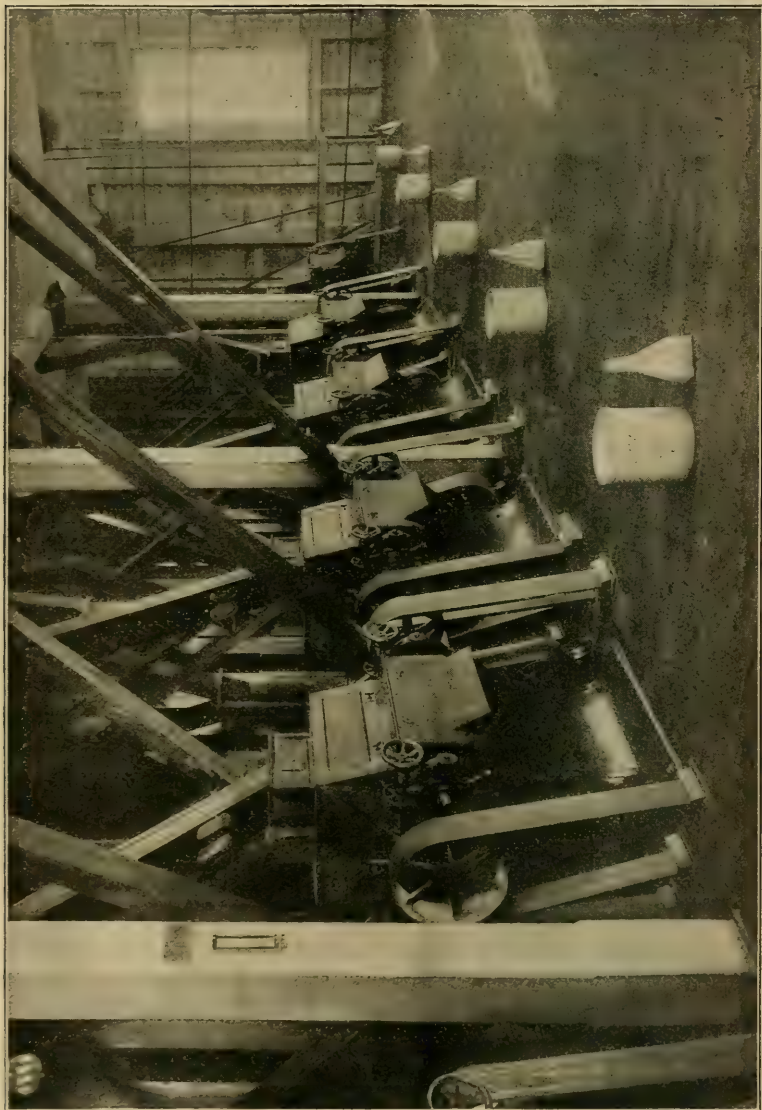


FIG. 8.—First floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the bags are to be dropped by hand. (Dean.)

such openings must be closed before fumigation is attempted or failure will result. As the gas has a tendency to rise, each floor should be treated as a unit by closing such openings as those formed by elevator shafts, stairways, etc. The small openings through which

belting passes and similar openings in the floor can be sufficiently well closed by crowding pieces of sacking firmly into them.

CHEMICALS NECESSARY FOR FUMIGATION.

The chemicals necessary for the generation of hydrocyanic-acid gas are potassium or sodium cyanid,³ sulphuric acid, and water.

Cyanid.—Either potassium cyanid or sodium cyanid can be used in fumigation, but trade conditions have made sodium cyanid more available for use and, as it is just as good and slightly cheaper, it is recommended. For a full discussion of the relative values of potassium and sodium cyanid for fumigating purposes, see Bulletin 90 of the Bureau of Entomology. Sodium cyanid for fumigation purposes should be 96 to 99 per cent guaranteed purity. The volume of gas liberated is in direct proportion to the purity of the cyanid, hence too much stress can not be placed on purchasing high-grade cyanid. Protection can be had by purchasing a cyanid guaranteed under the Federal insecticide act; the analysis on the label should show that the cyanid is at least as pure as follows:

Sodium cyanid (NaCN), 96 to 99 per cent, analysis.

	Per cent.
Cyanogen (CN), not less than-----	51.3
Sodium (Na), not more than-----	43.7
Inert substances, not more than-----	4.0
Chlorids, not more than-----	1.4

High-grade cyanid can be purchased in tin cans containing 50, 100, or 200 pounds. For ease in handling and preparing doses, it is convenient to purchase brands of cyanid in which the material is divided into lumps weighing approximately 1 ounce each. Cyanid decomposes slowly when exposed to the air, hence such cyanid as remains unused after a fumigation should be protected by being placed in an air-tight receptacle. Where this can not be done, the filling in of the original container with firmly packed sacking will greatly retard decomposition.

Sulphuric acid.—Commercial sulphuric acid (H_2SO_4) 92 to 94 per cent pure (66° Baumé), free from nitric acid, arsenic, lead, and zinc, should be used. It may be made from pyrites or pure brimstone, so long as impurities are eliminated. Acid is usually purchased in iron drums containing 800 to 1,500 and 2,000 pounds, though when used in smaller quantities it can be had in glass carboys of about 100 pounds capacity. Pure acid is colorless and about twice as heavy as water; its specific gravity is 1.83. When stored in iron drums it

³ Recent developments in liquid hydrocyanic acid indicate that sooner or later its use will replace this long established method of generating gas by the mixing of chemicals in containers.

frequently has a milky white color, especially at the bottom of the drum, due to the presence of sulphate of iron resulting from the

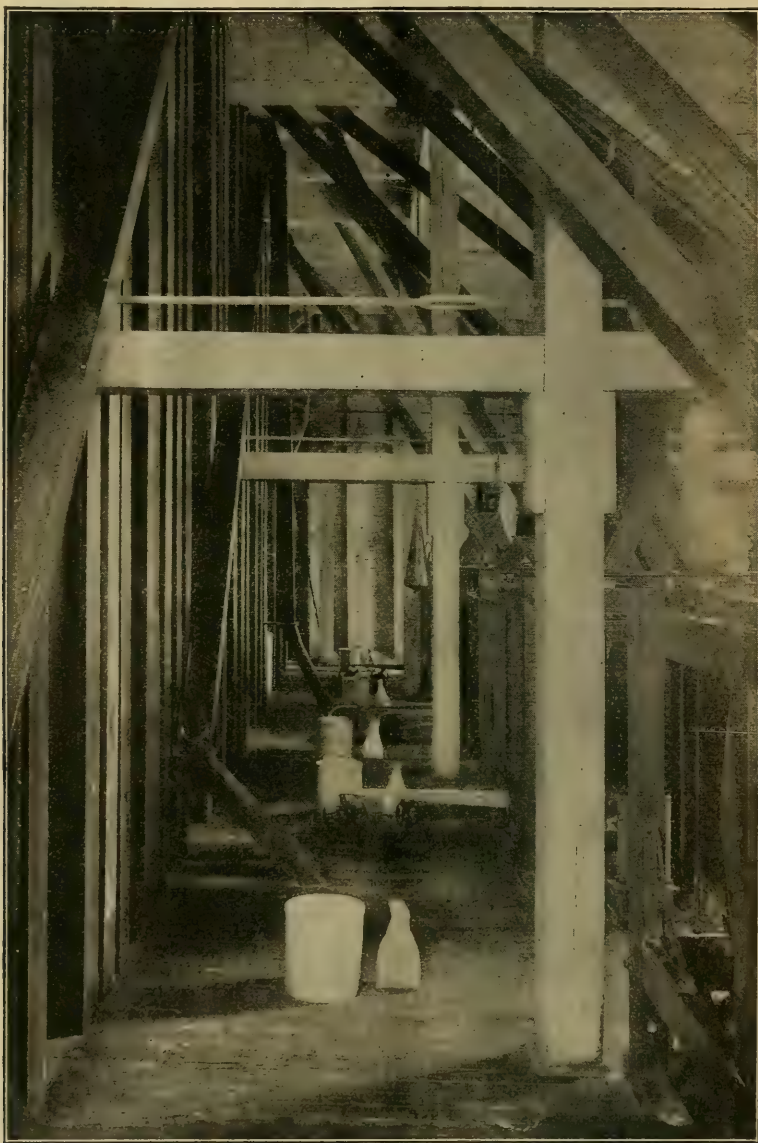


FIG. 9.—Second floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the bags are to be dropped by hand. (Dean.)

action of the acid upon iron either before or after the acid is placed in the drum. This sediment does not affect the value of the acid

unless present in excessive quantities. In estimating the amount of acid required it is sometimes convenient to know that $1\frac{1}{2}$ pints of acid

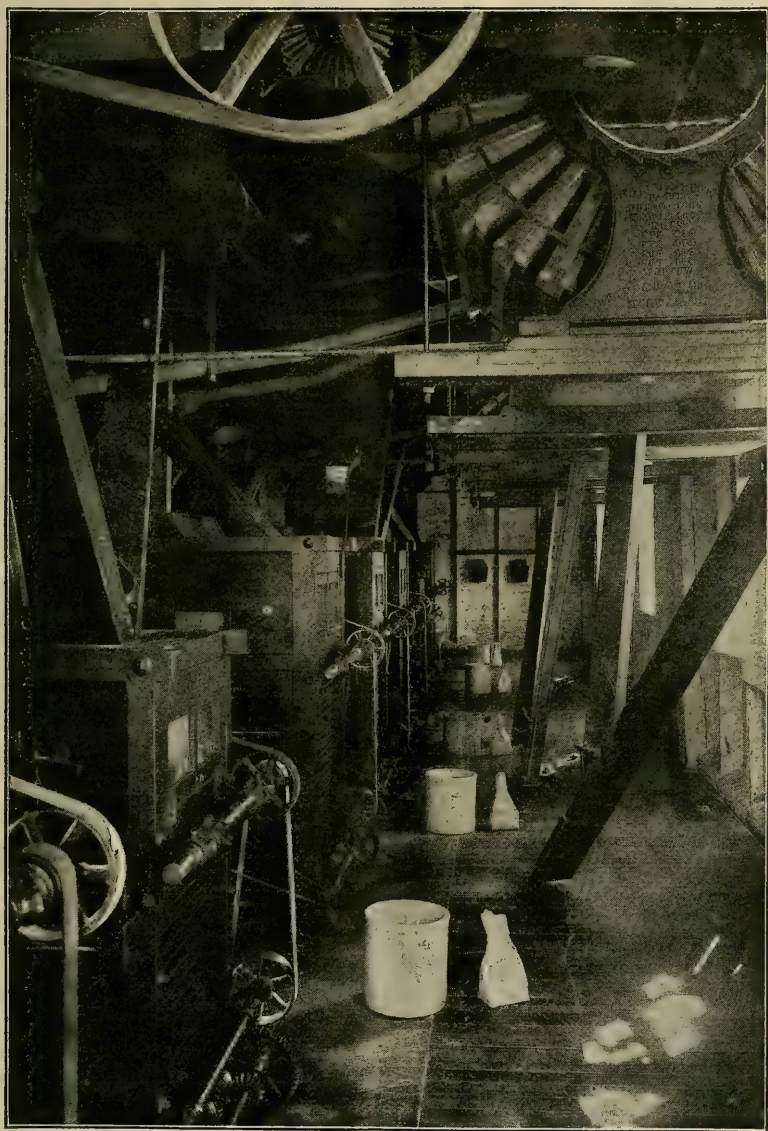


FIG. 10.—Third floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the bags are to be dropped by hand. (Dean.)

by liquid measure is required for each pound of cyanid when the following formula is used.

$$183545^{\circ}-20-3$$

PROPORTION OF CHEMICALS.

Hydrocyanic-acid gas is generated by mixing in proper proportion sodium cyanid, sulphuric acid, and water. These should be combined as follows:

- 1 ounce, by weight, of sodium cyanid.
- 1½ ounces, liquid measure, of sulphuric acid.
- 2 ounces, liquid measure, of water.

This is known as the 1-1½-2 formula. Slightly varying formulas have been recommended, but this 1-1½-2 formula yields good results.

EQUIPMENT FOR GENERATING GAS.

The equipment for generating gas may be very simple and should include the following:

Containers for generating the gas.—For mill fumigation, 4-gallon earthenware stone crocks, well glazed, such as may be purchased at any hardware store, have proved very satisfactory. Four-gallon crocks (see figs. 8 to 14) will receive a charge containing a maximum of 4 pounds of cyanid. Fumigation does not injure them for other purposes provided they are properly cleaned. Where very large spaces are to be fumigated strong water-tight wooden barrels have frequently been used. Untreated oil barrels in good condition have served for several fumigations without marked deterioration, where care is taken to add the acid slowly and to rinse thoroughly after using. A 50-gallon barrel will accommodate with ease a charge of 20 to 30 pounds. Containers holding larger quantities of solution are more difficult to remove and empty than smaller ones, and this is an important item. Good barrels sufficiently small to fit easily into an ordinary galvanized-iron washtub (fig. 7) and receive charges of 15 to 30 pounds of cyanid are very satisfactory when buildings are so arranged that they can be easily removed and emptied. If the tubs are partly filled with water to which have been added several handfuls of ordinary salsoda, there is no danger that the acid will spill out onto the floor during the chemical reaction which produces the gas, and the handles of the tub make it easy for two men to remove the tub and barrel at the same time after fumigation.

Measuring and carrying equipment.—Scales are needed for weighing cyanid. Glass graduates of 16 or 32 ounce capacity should be used for measuring acid and water. One or two gallon granite ware cups and pitchers are very convenient and safe for carrying acid. Ordinary granite ware buckets in good condition can be used very satisfactorily in carrying acid from carboys to generators, though these should be carefully washed immediately after use and not allowed to stand with acid in them. Containers of tin must not be used.

Sacks.—Sacks for holding the individual charges of cyanid are needed. When 4-gallon crocks are used common manila paper sacks, sizes 8 and 10, such as may be had of any grocer, are the best

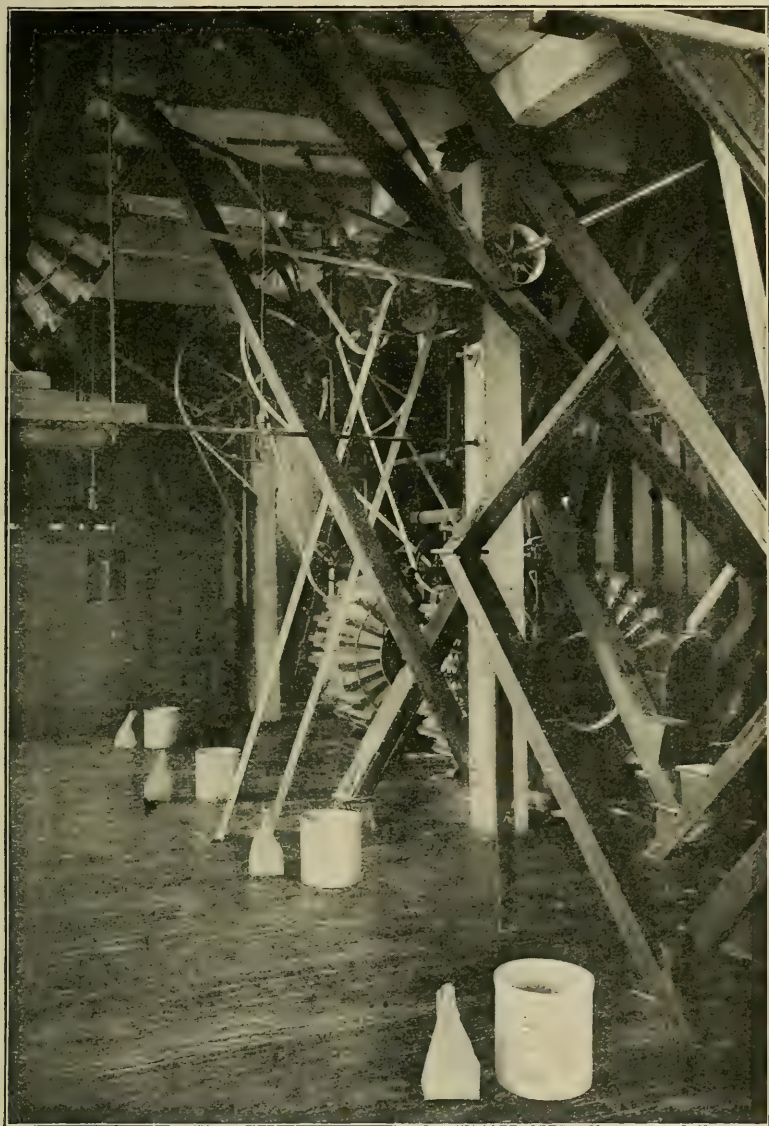


FIG. 11.—Fourth floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the bags are to be dropped by hand. (Dean.)

in which to place the cyanid. The cyanid is placed in the smaller sack, after which the smaller sack is slipped within the larger one. Sacks of heavy or heavily glazed paper should not be used, for

they retard the action of the acid upon the cyanid. Where larger doses must be carried old bran sacks may be used for the cyanid.

Protection against burns and charring.—Persons engaged in fumigation according to the method described in this bulletin invariably receive slight injuries to their clothing in the form of acid burns due to spattering and dripping of acid. Only the oldest clothing should be worn. A saturated solution of common washing soda crystals (sodium carbonate) should be at hand ready to apply to hands, face, or floor to neutralize acid splatterings that may occur. When acid is purchased in iron drums a sufficient number of 5 to 10 gallon glass carboys in the usual wooden frames to hold all acid

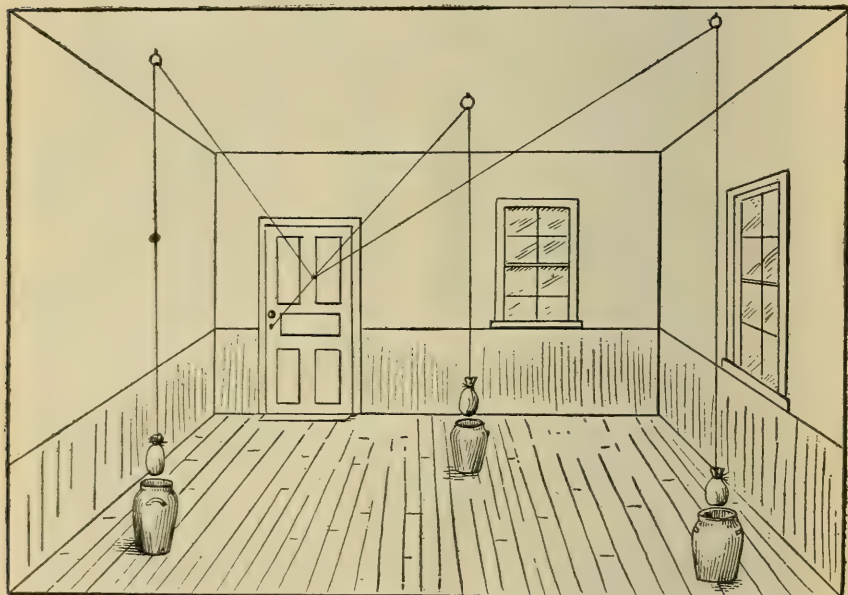


FIG. 12.—Diagram showing "stringing method" used in generating hydrocyanic-acid gas. The number of generators connected with the main cord may vary to fit the need of individual cases. (Chittenden.)

needed for the fumigation, should be provided to hasten the measuring of the acid. To guard against injury to the mill flooring, the acid should be measured outside the mill; or if this work is done within the mill old sacks and sawdust should be used liberally to prevent any acid spilled during the work from damaging the floor.

Provision for ventilating rooms after fumigation.—Care should be taken to provide for the ventilation of rooms or buildings after fumigation. It is dangerous to enter rooms to open windows from within although experienced fumigators often take such risks. Ingenuity can be depended upon to discover a way to open windows, transoms, or skylights from the outside by means of cords or wires.

ESTIMATING SPACES.

After a decision to fumigate has been made, the amount of space to be fumigated must be determined by securing the inside measurements of the length, width, and height of each room. No deductions should be made for machinery, bins, etc.

AMOUNT OF CHEMICALS NEEDED.

Once the cubic contents have been determined the amount of chemicals needed can be calculated easily. In the treatment of single tight rooms 1 ounce of cyanid is recommended for each 100 cubic feet of space. Where a reasonably tight mill has 4 or 5 floors the following standard, suggested by Dean, should be followed, as the gas is light and has a tendency to concentrate on the upper floors. Use 1 pound of sodium cyanid to each 1,000 cubic feet of space in the basement, to each 1,200 cubic feet of space on the first floor, to each 1,300 cubic feet of space on the second floor, to each 1,500 cubic feet of space on the third floor, and to each 1,600 cubic feet of space on the fourth and fifth floors. When buildings are rather loosely constructed, a larger amount of cyanid will be needed, but no directions can be given that will be as useful in determining the amount necessary to offset the looseness of individual mills as one or two experimental fumigations.

According to the $1-1\frac{1}{2}-2$ formula recommended on page 18, for each 100 pounds (1,600 ounces) by weight of cyanid required there will be needed also 2,400 fluid ounces of sulphuric acid.

NUMBER OF GENERATORS REQUIRED.

If 4-gallon crocks are used for generating the gas, one crock will be needed for each 4 pounds of cyanid required, or for each 6,400 cubic feet of space, when 1 ounce of cyanid is used to each 100 cubic feet of space. Where larger generators are used, as discussed on page 18, determine the amount of cyanid to be used in each container and use it to divide the total cyanid required for the building or room to secure the number of generators needed. It is always well not to overtax the capacity of a generator.

PLACING OF GENERATORS.

In placing the generators or jars, care must be taken to have them sufficiently distant from machinery, belting, sacks, walls, etc., so that there may be no danger of injury from spattering during gas generation. The reader is directed to examine carefully figures 8 to 11 for illustrations of how best to arrange generators. In using crocks it is always best to place beneath each crock some old sacking or papers, as not infrequently there is a slight spattering of the floor

close to the crocks during the chemical action which forms the gas. This is particularly true when a maximum charge for any container is used.

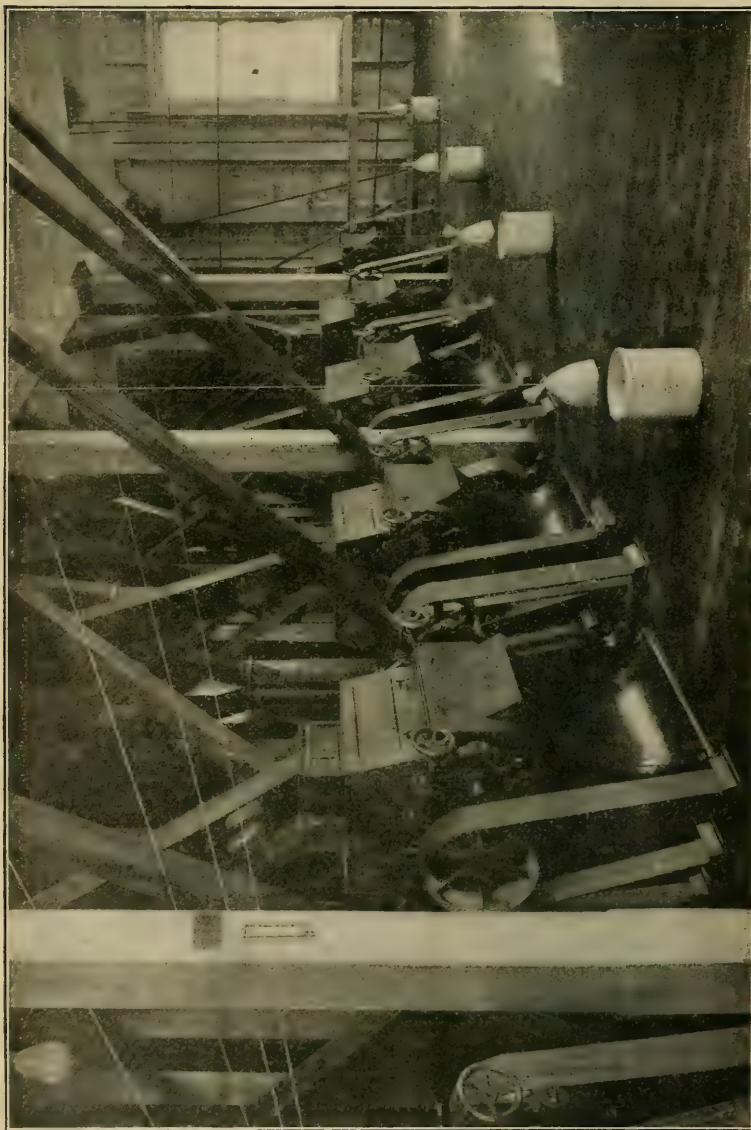


FIG. 13.—First floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the string system is to be used. (Dean.)

ORDER OF ASSEMBLING CHEMICALS FOR FINAL GENERATION OF GAS.

Having decided upon the number of generators for each floor and the amount of charge for each, the generators should be well distributed. The proper amount of water should then be measured out

and poured into each container. The acid should always be added to the water and never vice versa. The mixing of water and sulphuric acid generates heat; hence care should be taken to pour the acid slowly into the water to prevent too rapid a rise in temperature, which might cause a cracking of the crocks. As the gas is formed best when the mixture of acid and water is warm, the acid should not be added until just before the fumigation is started. As soon as the acid is poured into the generators the cyanid, which has already been weighed out into proper amounts and placed in sacks, should be distributed, one sack by each generator, as illustrated in figures 8 to 11.

DROPPING OF THE CYANID.

By this time everything should be in readiness for the generation of the gas. The building has been tightly closed, except for the doors or windows through which those who drop the cyanid will leave the building. Provision has been made for ventilating after fumigation (p. 20), the building has been cleaned (p. 13), made tight (p. 13), and manholes, slide doors, etc., in spouts, elevator legs, etc., have been opened, and all persons have been accounted for, those not assigned to dropping cyanid having left the building. Starting on the top floor, begin dropping the cyanid carefully, though quickly, into the generators, starting at the jars most distant from the exit and working rapidly toward the exit. This requires quick, cool-headed action. If a charge of cyanid is overlooked never go back to drop it; let it go—your safety comes first. When the last charge has been dropped leave the floor, closing the door behind, and repeat the operation on each successive lower floor.

When the person in charge feels that it is not wise to attempt to drop all charges of cyanid by hand because of difficulties in the way of retreat the *stringing method should be employed*. Novices often resort to this method, though experienced fumigators do not, except in difficult situations. Where floors are so crowded with machinery that a hasty exit can not be made, or in dropping charges in the basement where one must run upstairs to the first floor before reaching the exterior the use of the stringing method will eliminate danger. This method consists in passing strong cord through conveniently arranged screw-eyes, each string finally passing from a central point at the exit to and through a screw-eye in the ceiling, so that it will hang directly over the spot where the generator is to be placed. (See figs. 12, 13, and 14, 4.) The strings should be so arranged that they may all be lowered into the jars by releasing one main string. This may be done by carrying the strings leading to each jar through screw-eyes in the ceiling or wall to one stout cord at the exit, as illustrated in figure 12. After the strings have



FIG. 1. GENERATOR TOO CLOSE TO BAGS OF FLOUR.



FIG. 2. GENERATOR TOO CLOSE TO BELTS AND BAG TOO LOW.



FIG. 3. GENERATOR TOO CLOSE TO BELTS AND BAG TOO HIGH.

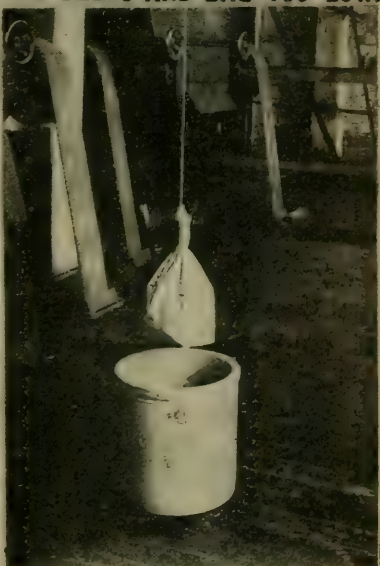


FIG. 4. CORRECT PLACING OF GENERATOR AND BAG.

FIG. 14.—The correct and incorrect placing of generators and bags of cyanid for hydrocyanic-acid gas fumigation. (Dean.)

been arranged, the generators should be placed and the water and acid added. Each generator should then be moved at least 2 feet away from where the cyanid will be suspended. Men should then go through the mill, tying firmly the sacks of cyanid to the strings, so that they will hang suspended about 2 or 3 inches above the tops of the generators. This done, the generators are placed beneath the suspended sacks. All persons should then leave the building. One man can now pass from the top to the lower floors lowering the cyanid into the generators by the simple manipulation of the central cord at the exit of each floor. The basement charge should, of course, be lowered last, and preferably by means of a cord running to the outside mill door or to the outside through some slight opening about a window.

CLOSING BUILDINGS AND GUARDING DOORS.

After the last charge has been set off and the last person has left the building, the door or doors used as exits should be locked. If such doors do not fit tightly, it will pay to paste strips of paper about their edges. Guards should be placed about the building in such a manner as to prevent persons entering the building. Guards should not stand where they can smell any amount of escaping gas. There should be several guards who keep in touch with one another, especially during the first one or two hours after the generation of gas.

TIME TO FUMIGATE AND LENGTH OF EXPOSURE.

Fumigate only during calm weather. During high winds the gas is carried to one side of the room or building and, unless the building is very tight, it is dissipated more quickly. Experiments have proved that insects are not active at temperatures lower than 50° to 60° F. and are not then so easily killed by the gas. Best results follow fumigations when the temperature is 70° F. or above. Everything for fumigation should be in readiness before dark. When possible the best time to fumigate is from Saturday afternoon to Sunday evening or Monday morning. At this time fewer people are about. The buildings should be allowed to remain closed for fumigation not less than 12 to 18 hours, though exposures of from 24 to 36 hours, when the building is tight and time is not an important factor, may effect a better killing of pests.

VENTILATION.

Several hours should elapse after a mill has been opened for ventilation before laborers are allowed to enter for regular work. The doors and the windows should be opened from without, according to provision made before fumigation. In opening windows and doors, open first those on the side of the building opposite to the

direction from which the wind is coming. After the preliminary ventilation has been in progress for one or two hours, it is safe for an operator to enter and open all windows and doors, but he should not remain in the building until it has been thoroughly aired. Specific directions as to the length of time for ventilation can not be given to meet all cases. Much depends upon the movement of air currents, the humidity of the air, and the rate of gas leaking from the building during the hours of fumigation. To be absolutely safe, buildings should be ventilated until there is no odor of gas before persons are allowed to resume their work. Men accustomed to fumigate soon acquire from experience knowledge which governs their action in remaining in buildings during the period of ventilation.

PROCEDURE AFTER VENTILATION.

After the mill has been ventilated thoroughly an operator should tour the building and make certain that no charge of cyanid was overlooked in the dropping or that no charge failed to be lowered into the generators if the stringing method was used. Any such charges should be removed from the building and placed with the stock of unused cyanid. Laborers should now be sent through the building to remove the generators, dumping their contents into a sewer or into a hole dug in the ground and giving the generators a thorough washing. If the chemical action has been complete, the residue in the jars after fumigation may not be particularly poisonous, yet it is acid, and will burn clothing and skin, and should be handled with care by reliable men. Men should be warned against deliberately inhaling any fumes that may be given off by the residue, either while they are removing the generators or emptying them. Generators that begin to bubble when disturbed should be avoided until the bubbling has ceased. When the residue has been absorbed, after it has been poured in the hole in the ground, the soil should be replaced.

EFFICIENCY OF FUMIGATION.

Experiments prove that in an air-tight chamber hydrocyanic-acid gas will penetrate in killing concentrations to a depth of 3 inches, but in mill fumigation the gas does not penetrate flour and mill products much beyond 1 inch, and often, particularly near the floor, not even that far. Not all mill pests are equally affected by the gas. In a mill infested by the Mediterranean flour moth hydrocyanic-acid gas is a very effective treatment. All stages of the moth, including the egg, if not covered with more than 1 inch of flour, are killed, but upon the several stages of the flour beetles, "bran bugs," and the cadelle the gas treatment is of less value. Many of these pests hide in places

inaccessible to the gas and escape treatment only to restock the mill later and offset the large numbers of their species killed during the fumigation.

FREQUENCY OF FUMIGATION.

Most millers who fumigate with hydrocyanic-acid gas apply the treatment once a year. Certain millers fumigate in the spring, give a second fumigation during midsummer, and a third during early fall. A more effective plan is to give two fumigations in July or August within three or four weeks of each other. Of the different stages of the moth, the egg stage is the most difficult to kill, and a certain number of eggs usually escape the first fumigation. If, then, a second fumigation is applied three to four weeks after the first, it will catch the worms that hatch from the eggs unaffected by the first fumigation, when they are in a stage easily killed by the gas; at that time they have not had an opportunity to develop into adult moths and lay more eggs. Fumigation is advocated only for the warm summer months.

EFFECTS OF HYDROCYANIC-ACID GAS UPON FLOUR.

Experiments conducted at the Kansas Agricultural Experiment Station, results of which are published in Bulletin No. 178 of that station, included fumigations of four grades of soft winter-wheat flour, consisting of a patent, a straight, a clear, and a low grade, and of three grades of hard winter wheat flour, consisting of a patent, a straight, and a low grade. Samples were fumigated at the maximum strength recommended for flour-mill fumigation, viz, 1 pound of cyanid to each 1,000 cubic feet of space. Flour was exposed to a temperature of 90° F in a tight chamber kept at constant temperature for a period of 12 hours. Dean, of Kansas, concludes:

It is only in the careful measurements employed in the test that any difference between the fumigated and the unfumigated flour is apparent at all. The only notable difference appears in the maximum volume of the dough in the test made immediately after fumigation, but not after thirty days. The finished loaf shows no deleterious effect from fumigation in any of the tests.

CONTROL BY HEAT.

It has been stated that fumigation with hydrocyanic-acid gas, effective as it is in controlling the Mediterranean flour moth in mills, does not control so satisfactorily the several stages of the flour beetles (*Tribolium confusum* Duv. and *T. ferrugineum* Fab.), the "bran bug" (*Laemophloeus minutus* Oliv.), the cadelle (*Tenebroides mauritanicus* L.), and the sawtoothed grain beetle (*Silvanus surinamensis* L.) These insects are naturally more resistant to the effect of gas, and secrete themselves in large numbers in cracks and accumu-

lations of fine stocks inaccessible to any gas. The flour beetles and the cadelle, the larval stages of which cause much trouble in flour, are in practically every flour mill in the country, except where remedial measures are successfully practiced. Inspection of ports in this country and in Europe through which the flour from many American mills is handled, either for domestic or for foreign trade, indicates that these insects just mentioned, which can not be controlled so satisfactorily by fumigation, are causing serious trouble, and that the large majority of the infestations originate at the mills.

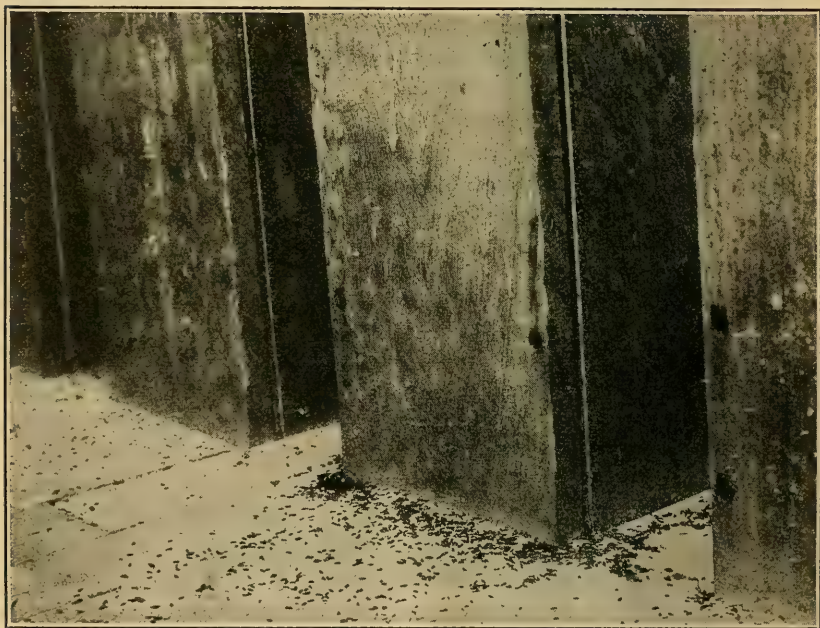


FIG. 15.—Photograph of elevator legs after application of the heat method of control. Note the large number of flour beetles which, on feeling the heat, have crawled out of the cracks of the wooden elevator legs and died upon the mill floor.

The most practical and effective method known to control all classes of mill-infesting insects is the application of high temperatures. (Fig. 15.)

Heat has been recognized as a control agent for many years in this country and in Europe. But its effectiveness as a control measure in flour mills was first demonstrated by professional experimental investigation by Prof. George A. Dean in several Kansas mills during the period 1910–1913.⁴ So successful were Dean's demonstrations that the heat method has been tested by the Federal Bureau of Entomology and by several State entomologists with the result that mills in

⁴ DEAN, GEORGE A., MILL AND STORED-GRAIN INSECTS. Kans. State Exp. Sta. Bul. 189, p. 139–236, 56 figs., 6 pl., July, 1913.

Kansas, Ohio, Nebraska, Illinois, Indiana, Iowa, southern Canada, Virginia, and elsewhere are equipped for and are using the heat method. The result of all this work is that to-day the heat method is recognized as the most effective, practical, and inexpensive of all treatments, and has the added advantage of being absolutely safe. The greatest expense is the original installation of radiating surface. Yet this expense is offset by the greater cheapness of the heat method as compared with any other effective control measure. Goodwin,⁴ an experimenter in Ohio, claimed in 1912 that for a mill of average size, forced to apply remedial measures, the cost of steam piping necessary to obtain killing temperatures was offset within five years by the saving due to the cheapness of the heat method.

HEAT APPLIED MOST EFFECTIVELY IN SUMMER.

It is advised that heat be applied during the summer months in order that the normally high temperatures then obtaining may be turned to the advantage of the miller. It is much easier to raise the temperature of a mill to the killing point when the outdoor temperature is 85° F. or above. It takes less fuel and less radiation surface and saves time. Take advantage of summer heat. Heat only in quiet weather; it is impossible to get uniformly good results during windy weather.

DEGREE OF HEAT NECESSARY.

A temperature of 118° F. to 125° F. in all parts of the mill is sufficient to kill mill pests. To obtain these killing temperatures in the least exposed parts, it is necessary to heat other portions to a still higher temperature unless greater care than usual is taken to distribute radiation surfaces according to the situation. For temperatures secured in various parts of mills heated experimentally with equipments already installed, see data in Tables I to XII.

USE OF STEAM HEAT.

Steam heat is the most satisfactory heat for raising mill temperatures to the killing point. A pressure of 25 to 50 pounds is recommended.

AMOUNT OF RADIATION REQUIRED.

The number of square feet of radiation required to heat a given number of cubic feet of space depends upon the number of doors and windows in a building and upon the general tightness of the structure. Because these factors vary so greatly in mills, a definite recommendation for amount of radiation surface can not be given. The engi-

⁴ GOODWIN, W. H., FLOUR MILL FUMIGATION. Bul. Ohio Agr. Exp. Sta., no. 234, p. 184, January, 1912.

neer of each establishment, aided by one or two experimental heatings, will be able to increase or reduce the radiation surface in various parts of the mill until provision is made for securing sufficiently high temperatures. One square foot of radiation is usually sufficient to heat from 50 to 100 cubic feet of space. A mill with sufficient radiation to heat it during winter to 70° F. without the heat of the running machinery can be heated readily in summer to 120° F. or 125° F. Dean suggests for a five-story building 1 square foot of radiation to each 50, 60, 75, 90, and 110 cubic feet of space for the first, second, third, fourth, and fifth floors, respectively; and in a mill of four floors, 1 square foot of radiation to each 50, 60, 75, and 100 cubic feet of space for the first, second, third, and fourth floors, respectively. The amount of radiation surface per linear foot and the linear feet of pipe per square foot of radiation surface for pipes of varying sizes are as follows:

Size of pipe, in inches.	Radiation surface per linear foot.	Linear feet of pipe per square foot of radiation surface.
1.....	0.346	2.9
1½.....	.434	2.3
1½.....	.494	2.0
2.....	.622	1.6
2½.....	.753	1.3

If steam pipe is used for radiation the 1½-inch or 1½-inch size is recommended as most practical.

HEAT DOES NOT INJURE EQUIPMENT.

Heating mills as recommended for the control of mill pests will not injure the mill structure or equipment. In the many heatings on record no injury has occurred to belting or machinery, or, by checking, to elevator legs, woodwork of bolters, and purifiers. Mills have been heated to as high as 150° F. for 30 hours without injury to any part.

Objection made that insurance companies will not permit the heat method of control is without foundation. Mr. William Reed, as secretary of the Mutual Fire Protection Bureau, representing eight of the principal millers' insurance companies, in a notice to all policy holders stated, "We propose to advocate the heating system for effective fumigation against the Mediterranean flour moth, weevil, and all other mill and grain infesting insects."

FLOUR NOT AFFECTED BY HEAT METHOD.

Results of baking tests made of patent hard-wheat flour, a low-grade hard-wheat flour, and a pancake flour have proved conclu-

sively that the heat method, even at several degrees of temperature higher than recommended for mill treatment, has no injurious effect upon the baking qualities of the flour. A low hard-grade wheat flour was subjected to a temperature of 140° F. for nine hours on three successive occasions (the second and third heatings occurring two and six weeks after the first heating), and a pancake flour was subjected to a temperature of 130° F. for 48 hours without injurious results.

EFFECT OF HEATING UPON MILL HUMIDITY.

Heating to kill mill insects greatly reduces the humidity in the mill. Insects die more quickly in a dry heat than in a moist heat. The relative humidity on the second floor of a mill at 10 a. m., when the heat was turned on, was 93 per cent; by 12 m. it had fallen to 40 per cent, and by 5.30 p. m. to 27 per cent. In a second mill the relative humidity at 6 a. m., when the heat was turned on, was recorded by a hygrograph as 72 per cent; during the first few hours following there was a rapid decrease to less than 40 per cent, and during the afternoon and throughout the night there was a still further decrease to 12 per cent.

IMPORTANT POINTS TO BE CONSIDERED IN THE SUCCESSFUL HEATING OF A MILL.

1. Steam pipes should be located near floor and arranged to give equal distribution of heat.
2. Provide water trap for drawing off accumulation of water in pipes.
3. Lower floors and floors with heavy machinery should have more radiating surface in proportion to cubic feet of space than upper floors and floors with light machinery.
4. Mill will heat more rapidly with a steam pressure of 25 to 50 pounds.
5. To take advantage of heat in machinery begin heating mill immediately after shutdown.
6. Stairways and elevator shafts should be closed, so as to make separate units of each floor.
7. Thermometers should be placed at different points on each floor that temperatures may be readily ascertained.
8. Time must be taken to reach desired temperatures.
9. A temperature of 118° F. to 125° F. is sufficient for any part of mill.
10. This temperature should be maintained for several hours to allow heat to penetrate all infested parts.
11. Do not attempt to heat on a windy, cold, or rainy day.

12. By beginning the heat process directly after shutting down mill Saturday afternoon and continuing until Sunday night or early Monday, there is no loss in producing hours.

EXPERIMENTAL DATA ON HEAT FUMIGATION.

The following temperatures and results were secured in experimental work by Dean (mills 1 to 4) and by Goodwin⁵ (mill 5).

MILL No. 1.

Brick building; day (July 7-8, 1912) calm, partly cloudy; outdoor maximum temperature 91° F., outdoor minimum temperature 73° F. Heating system, steam pipes along walls, except in space beneath first floor where radiators are used. Steam pressure of about 20 pounds maintained during experiment. Capacity of mills, 600 barrels.

ON FIRST AND SECOND FLOORS.

Location and reading of thermometers.—The thermometers were located on these floors as follows: No. 1, in 2 inches of flour in elevator boot on floor, 8 feet beneath steam pipes; No. 2, hanging in middle of room, 5 feet high, 15 feet from steam pipes; No. 3, in 2 inches of flour in elevator boot on floor, 12 feet from steam pipes; No. 4, hanging in the open, 4 feet high, 15 feet from steam pipes; No. 5, between the rolls in a roll, 11 feet from steam pipes; No. 6, hanging in the open, 6 feet high, near roll machinery.

TABLE I.—*Data showing rise in temperatures on first and second floors.*

Time of day.	First floor: Capacity, 28,728 cubic feet; radiation, 525 square feet.			Second floor: Capacity, 28,728 cubic feet; radiation, 560 square feet.		
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
	° F.	° F.	° F.	° F.	° F.	° F.
July 7, 1912:						
10.30 a. m.	83	90	86	98	97	99
11.30 a. m.	83	94	88	105	97	106
12.30 p. m.	84	98	91	110	98	111
2.30 p. m.	88	104	96	117	100	118
3.30 p. m.	90	106	100	120	102	121
4.30 p. m.	93	107	102	123	104	123
5.30 p. m.	94	110	103	125	105	125
7 p. m.	95	110	107	127	108	127
8.30 p. m.	97	113	108	129	109	129
9.30 p. m.	98	115	108	130	111	129
July 8, 1912:						
9 a. m.	100	122	116	140	122	140
11 a. m.	106	124	117	142	125	142
12 m.	106	125	118	144	126	144
2 p. m.	106	128	118	144	127	144
4 p. m.	107	129	120	147	129	147
5.30 p. m.	108	129	121	146	131	145

ON THIRD AND FOURTH FLOORS.

Location and reading of thermometers.—Thermometers were located on these floors as follows: No. 1, hanging in the open, 5 feet high, 15 feet from steam

⁵ Op. cit.

pipes; No. 2, in flour in a conveyor near floor, 12 feet from steam pipes; No. 3, in flour in conveyor, 6 feet high, 15 feet from steam pipes; No. 4, hanging in the open, 5 feet high, 12 feet from steam pipes; No. 5, in flour, in a conveyor near floor, 12 feet from steam pipes; No. 6, in flour, in a conveyor near floor, 12 feet from steam pipes.

TABLE II.—Data showing rise in temperatures on third and fourth floors.

Time of day.	Third floor: Capacity, 31,122 cubic feet; radiation, 460 square feet.		Fourth floor: Capacity, 43,092 cubic feet; radiation, 400 square feet.			
	Thermometer.					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 7, 1912:	° F.	° F.	° F.	° F.	° F.	° F.
10.30 a. m.	95	85	89	96	88	88
11.30 a. m.	100	88	91	100	90	90
12.30 p. m.	105	91	95	105	92	91
2.30 p. m.	114	100	102	114	99	97
3.30 p. m.	116	102	103	116	101	99
4.30 p. m.	119	105	107	118	103	101
5.30 p. m.	122	107	108	119	106	103
7 p. m.	124	111	111	120	109	106
8.30 p. m.	126	113	113	121	111	109
9.30 p. m.	127	114	114	122	112	110
July 8, 1912:						
9 a. m.	133	126	125	127	118	117
11 a. m.	138	127	125	129	119	118
12 m.	139	127	126	132	120	119
2 p. m.	141	128	128	133	121	120
4 p. m.	143	128	131	138	124	122
5.30 p. m.	145	129	131	138	124	122

RESULTS OF HEATING MILL NO. 1.

One hundred per cent of all insects were killed on the second, third, and fourth floors. All insects were killed on the first floor, except those in elevator boots on the floor, where killing temperatures were not secured except directly over the radiators in the space beneath the floor.

MILL No. 2.

Brick building; day (July 21, 1912) partly cloudy and calm; maximum outdoor temperature 97° F.; minimum outdoor temperature 74° F. Heating system, steam pipes along wall and a few radiators. Steam pressure of about 100 pounds maintained during heating. Capacity of mill, 1,000 barrels.

BASEMENT AND FIRST FLOOR.

Location and reading of thermometers.—No. 1, in flour in an elevator boot resting on floor, 5 feet from steam pipes; No. 2, hanging in the open, 6 feet high, 10 feet from steam pipes; No. 3, in flour in an elevator boot resting on floor, 15 feet from steam pipes; No. 4, in flour in an elevator boot resting on floor, 10 feet from steam pipes; No. 5, hanging in the open, 6 feet high, 15 feet from steam pipes; No. 6, in flour in a roll, 20 feet from steam pipes; No. 7, in flour in a roll in the cleaning room, 5 feet from a radiator.

TABLE III.—Data showing rise in temperatures in basement and on first floor.

Time of day.	Basement: Capacity, 33,790 cubic feet; radiation, 1,020 square feet				First floor: Capacity, 40,040 cubic feet; radiation, 780 square feet.		
	Thermometer—						
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
July 21, 1912:	° F.	° F.	° F.	° F.	° F.	° F.	° F.
8 a. m.	96	128	98	98	130	121	97
10 a. m.	97	134	104	98	138	123	100
12 m.	100	136	105	98	140	123	102
2 p. m.	102	136	107	102	140	124	108
4 p. m.	104	38	108	106	142	125	111
6 p. m.	103	140	109	109	143	127	113
8 p. m.	103	143	109	109			
10.30 p. m.	102	145	113	109	146	131	119

SECOND AND THIRD FLOORS.

Location and reading of thermometers.—No. 1, hanging in the open, 6 feet high, 15 feet from steam pipes; No. 2, in flour in bottom of an elevator boot, 15 feet from steam pipes; No. 3, in flour on bolting cloth in a reel, 12 feet from radiation (cleaning room); No. 4, hanging in the open, 5 feet high, 12 feet from steam pipes; No. 5, in flour in a conveyor, 14 feet from steam pipes; No. 6, hanging in the open, 5 feet high, 10 feet from radiator (cleaning room).

TABLE IV.—Data showing rise in temperature on second and third floors.

Time of day.	Second floor: Capacity, 43,120 cubic feet; radiation, 800 square feet.		Third floor: Capacity, 43,120 cubic feet; radiation, 900 square feet.			
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
	° F.	° F.	° F.	° F.	° F.	° F.
July 21, 1912:						
8 a. m.	137	112	110	120	108	116
10 a. m.	144	119	113	126	114	121
12 m.	147	122	115	131	116	125
2 p. m.	151	127	121	136	120	130
4 p. m.	153	130	124	138	123	132
6 p. m.	153	128	126	139	124	134
8 p. m.	154	128	128	141	127	136
10.30 p. m.	156	130	129	142	129	138

RESULTS OF HEATING MILL NO. 2.

One hundred per cent of the insects were killed everywhere except in elevator boots resting on the concrete floor in the basement.

MILL NO. 3.

Brick building; day (July 27–28, 1912) calm and partly cloudy; outdoor maximum temperature 105° F.; outdoor minimum temperature 73° F.; heating system, steam pipes along wall; steam pressure of about 100 pounds maintained during heating. Capacity of mill, 1,000 barrels.

BASEMENT, FIRST, AND SECOND FLOORS.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high; No. 2, in flour in an elevator boot resting on floor; No. 3, in flour in an elevator boot resting on floor; No. 4, in some bran in a roll, 12 feet from steam pipes; No. 5, hanging in the open, 5 feet high, 10 feet from steam pipes; No. 6, in flour in an elevator boot resting on floor; No. 7, hanging in the open, 5 feet high, 15 feet from steam pipes; No. 8, in flour in a conveyor, 20 feet from steam pipes; No. 9, in 4 inches of flour near floor, 8 feet from steam pipes.

TABLE V.—Data showing rises in temperatures in basement and on first and second floors.

Time of day.	Basement: Capacity, 23,199 cubic feet; radiation, 260 square feet.			First floor: Capacity, 29,526 cubic feet; radiation, 210 square feet.			Second floor: Capacity, 27,417 cubic feet; radiation, 168 square feet.		
	Thermometer—								
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.
July 27-28:	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
9.30 p. m.	113	104	102	110	118	105	117	108	109
11.30 p. m.	112	102	102	113	121	107	120	111	112
July 28:									
6.30 a. m.	109	96	100	116	123	110	126	114	120
7.30 a. m.	110	99	99	118	124	110	126	116	120
9.30 a. m.	118	108	110	120	128	113	130	117	121
11.30 a. m.	122	109	109	122	129	114	131	119	124
12.30 p. m.	122	110	110	123	130	115	132	131	134
2.30 p. m.	124	113	113	124	131	116	133	122	126
4.30 p. m.	128	114	115	126	134	119	136	125	128
5.30 p. m.	129	115	115	127	135	120	137	127	128
7.30 p. m.	130	119	118	130	137	123	138	128	130
9.30 p. m.	130	117	117	130	137	123	138	128	130
11 p. m.	130	118	118	.....	.....	.....	.....	.....	.....
July 29:									
1 a. m.	134	120	120	.....	.....	.....	.....	.....	.....
3 a. m.	136	122	122	.....	.....	.....	.....	.....	.....
4.30 a. m.	136	122	122	.....	.....	.....	.....	.....	.....

THIRD FLOOR AND DECK.

Location and reading of thermometers.—No. 1, in flour in a conveyor near the floor, 20 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 12 feet from steam pipes; No. 3, in a pile of flour on the floor, 10 feet from steam pipes; No. 4, hanging in the open, 5 feet high; No. 5, in refuse flour on the base of a dust collector near the floor; No. 6, in flour 3 feet from the floor.

TABLE VI.—Data showing rise in temperatures on third floor and deck.

Time of day.	Third floor and deck: Capacity, 45,343 cubic feet, including deck; radiation, 326 square feet; radiation, deck, none.					
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 27-28:	° F.	° F.	° F.	° F.	° F.	° F.
9.30 p. m.	111	127	111	123	113	115
11.30 p. m.	113	122	113	124	115	116
6.30 a. m.	118	128	119	130	120	122
7.30 a. m.	119	130	120	131	122	124
9.30 a. m.	122	132	122	134	125	126
11.30 a. m.	124	136	124	138	127	129
12.30 p. m.	125	137	126	138	128	130
2.30 p. m.	128	139	128	141	133	134
4.30 p. m.	129	141	129	143	133	136
5.30 p. m.	130	142	130	144	134	137
7.30 p. m.	132	142	132	144	136	138
9.30 p. m.	132	141	131	143	136	138

RESULTS OF HEATING MILL NO. 3.

One hundred per cent of insects were killed on the first to deck floors. In the basement 90 per cent were killed; the steam-pipe exhaust opened into a pit beneath the basement floor and this allowed the escaping steam to enter the basement and keep the air moist.

MILL No. 4.

Frame building; day (July 28, 1912) partly cloudy with light breeze; outdoor maximum temperature 95° F.; outdoor minimum temperature 72° F. Heating system, steam pipes along wall, steam pressure of about 80 pounds maintained during heating. Capacity, 1,000 barrels.

FIRST FLOOR.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high, 15 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 18 feet from steam pipes; No. 3, resting on a roll in a roller, 12 feet from steam pipe; No. 4, in 2 inches of flour near floor, 5 feet from steam pipes; No. 5, in flour in a conveyor near floor, 20 feet from steam pipes; No. 6, hanging in the open 6 feet high, 20 feet from steam pipes.

TABLE VII.—Data showing rise in temperature on first floor.

Time of day.	First floor: Capacity, 34,790 cubic feet; radiation 262 square feet.					
	Thermometers—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 28, 1912:	° F.	° F.	° F.	° F.	° F.	° F.
8 a. m.	98	96	105	90		
10 a. m.	104	101	106	94	96	110
12 m.	110	106	108	97	104	113
2 p. m.	114	111	109	102	105	117
4 p. m.	118	115	110	107	108	120
6 p. m.	120	116	110	110	110	122
8 p. m.	121	117	112	113	112	123
9 p. m.	121	118	113	114	112	126
9.30 p. m.	121	118	113	114	112	126

SECOND FLOOR.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high, 22 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 18 feet from steam pipes; No. 3, in 3 inches of bran near floor, 5 feet from steam pipes; No. 4, in flour in an elevator boot resting on floor, 17 feet from steam pipes; No. 5, in an oven in a laboratory, 5 feet high and 3 feet from steam pipes; No. 6, in flour in an elevator boot resting on floor, 30 feet from steam pipes.

TABLE VIII.—Data showing rise in temperature on second floor.

Time of day.	Second floor: Capacity, 38,269 cubic feet; radiation, 190 square feet.					
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 28, 1912:	° F.	° F.	° F.	° F.	° F.	° F.
8 a. m.	98	94	93	92		
10 a. m.	102	100	93	94	120	94
12 m.	108	104	95	99	128	97
2 p. m.	114	112	99	104	134	100
4 p. m.	118	115	103	107	139	106
6 p. m.	120	118	106	108	142	106
8 p. m.	122	118	110	110	143	108
9.30 p. m.	122	119	110	112	144	110

THIRD FLOOR.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high, 22 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 20 feet from steam pipes; No. 3, in flour in conveyor, 6 feet high, 8 feet from steam pipes; No. 4, in flour in a purifier, 4 feet high, 13 feet from steam pipes; No. 5, in flour in an elevator boot resting on floor, 4 feet from steam pipes; No. 6, in flour in a conveyor near floor, 11 feet from steam pipes.

TABLE IX.—Data showing rise in temperatures on third floor.

Time of day.	Third floor: Capacity, 49,375 cubic feet; radiation, 267 square feet.					
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 28, 1912:	° F.	° F.	° F.	° F.	° F.	° F.
8 a. m.	98	95	94	96	96	102
10 a. m.	104	101	100	98	100	99
12 m.	109	106	104	104	104	103
2 p. m.	115	112	108	108	108	108
4 p. m.	120	117	112	112	112	112
6 p. m.	124	121	116	116	114	115
8 p. m.	126	123	119	118	116	114
9.30 p. m.	127	124	120	122		

FOURTH FLOOR AND DECK.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high, 26 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 28 feet from steam pipes; No. 3, in flour in an elevator boot, 6 inches from floor, 24 feet from steam pipes; No. 4, in flour in a conveyor near floor, 13 feet from steam pipes; No. 5, in flour in a conveyor near floor, 22 feet from steam pipes; No. 6, hanging in the open, 5 feet from floor; No. 7, in flour in a conveyor near floor.

TABLE X.—Data showing rise in temperatures on fourth floor and deck.

Time of day.	Fourth floor and deck: Capacity, 69,580 cubic feet, including deck; radiation, 310 square feet; radiation, deck, none.						
	Thermometer—					Deck thermometer—	
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
July 28, 1912:	° F.	° F.	° F.	° F.	° F.	° F.	° F.
9 a. m.	101	98	93	94	97	104	100
10 a. m.	103	100	95	96	92	106	99
12 m.	110	107	102	100	98	114	112
2 p. m.	116	114	107	102	100	122	113
4 p. m.	122	120	113	106	105	126	118
6 p. m.	126	123	116	110	109	128	123
8 p. m.	126	123	118	115	113	127	125
9.30 p. m.	127	124	118	114	113	127	126

RESULTS OF HEATING MILL NO. 4.

One hundred per cent of the insects were killed on the third, fourth, and deck floors, 95 to 100 per cent were killed on the second, and 90 to 95 per cent were killed on the first floor.

MILL No. 5.

Frame structure, not tightly constructed and with many small openings where lap-siding boards had sprung apart or warped. There are also small openings about doors. Building too loosely constructed for satisfactory fumigation with gas. Day (July 10-11, 1911) calm except for slight breeze blowing from southwest after 9 a. m. July 11, which somewhat affected temperatures on that side of building. Mill equipped with radiators for heating by steam during winter. Outdoor maximum temperature 95° F. No mention made of steam pressure or minimum outdoor temperature.

FIRST AND SECOND FLOORS.

Location and reading of thermometers.—No. 1, near airshaft; No. 2, set 5 inches deep in floor; No. 3, in boot of elevator; No. 4, three feet from floor; No. 5, on inside of outer wall; No. 6, near floor in elevator leg; No. 7, on support post; No. 8, on outside wall; No. 9, in a roll.

TABLE XI.—Data showing rise in temperatures on first and second floors.

	First floor.					Second floor.				
Time of day.	Thermometer—									
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 1.	No. 2.	No. 3.	No. 4.	
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	
7.30 p. m.	90	86	100	102	95	107	102	101	107	
9.30 p. m.	94	91	102	124	101	120	115	109	119	
11.30 p. m.	95	95	106	127	103	122	117	116	122	
6 a. m.	96	103	108	131	108	128	124	118	129	
8 a. m.	99	104	112	134	111	130	127	120	131	
10 a. m.	104	107	113	141	115	135	132	125	137	
12 m.	106	109	114	141	116	137	133	126	137	
2 p. m.	106	110	115	141	116	137	134	124	138	
3 p. m.	107	111	116	141	118	-----	-----	-----	-----	

THIRD FLOOR AND DECK.

Location and reading of thermometers.—No. 1, in conveyor, in 3 inches of flour; No. 2, in elevator leg; No. 3, near outside wall; No. 4, in bolter; No. 5, on a post on the deck built on third floor.

TABLE XII.—Data showing rise in temperatures on third floor and deck.

Time of day.	Thermometer—				
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
	° F.	° F.	° F.	° F.	° F.
7.30 p. m.	93	104	102	102	104
9.30 p. m.	104	113	113	116	113
11.30 p. m.	107	118	116	121	116
6 a. m.	118	125	125	129	129
8 a. m.	119	129	129	133	137
10 a. m.	122	134	138	138	140
12 m.	124	135	136	139	142
2 p. m.	127	136	136	139	142

RESULTS OF HEATING MILL NO. 5.

All insects were killed on the second and third floors. Dead beetles and larvæ could be found beneath 3 inches of flour. All insects were killed on the first floor except near air shaft (thermometer No. 1) and those buried 5 inches in flour (thermometer No. 2).

CONTROL BY FREEZING.

If an infested mill is so equipped that it can be opened to low outdoor temperatures without injury to equipment, freezing is an inexpensive and valuable remedy for the flour moth. Turning off all heat and opening the mill to a temperature of zero or lower for from 3 to 10 nights continuously, or at intervals, has often proved effective in destroying the moth in its different stages. Mills in the northern United States and in Canada, where temperatures of 20 to 30 degrees below zero (Fahrenheit) are often experienced, have used this method of control with good results. Mills located farther south where freezing temperatures do not run so low or prevail continuously for any length of time have had little or no benefit from attempts to utilize cold weather.

CONTROL BY SMUDGES.

Control by means of smudges in the form of sulphur or tobacco fumes, etc., is depended upon rather extensively in many mills to reduce flour-moth injury. With smudges one can only expect to reduce the flour moth temporarily by killing the adult moths and certain of the immature stages. The fumes generated are not strong enough to kill as do hydrocyanic-acid gas fumigation and high temperatures. In rambling, loosely constructed buildings, where control by heat and hydrocyanic-acid gas is not practical, smudges, coupled with constant cleaning, have their value. The moth miller or adult is the most easily killed of the different stages of the flour moth and is the form killed in largest proportions by smudges. Since each female moth is the potential parent of several hundred larvæ, one can appreciate the value of the persistent use of smudges. The chief drawback to dependence upon smudges is that they never completely exterminate the moth. Smudges, to accomplish satisfactory results, must be applied frequently, and are therefore costly in the long run. One thorough application of heat rids a mill of the flour moth for long periods if provision is made against reinfestation from without. Flying moths may be found as soon as one day after the application of a smudge.

CONCLUSION.

Control of insect pests in flour and cereal mills has become a very important feature of food conservation and of mill construction and operation. Losses caused by mill insects to mill owners and the ad-

vantages of modern mill construction are working hand in hand to bring about a constant change for the better. Putting into practice methods of control advocated in this bulletin will make it possible for milling concerns to place upon the market a product reasonably free from infestation. When insect sanitation is conscientiously applied, millers can state that blame often heaped upon them by brokers, retail grocers, and the public at large is due to one or more of several known conditions connected with warehousing and transportation, for the miller is in no way responsible.

There are a number of serious insect pests of flour mills. The long-established pests in American mills do not interfere noticeably with operation of mill machinery. With the spread from Europe to the United States of the Mediterranean flour moth (p. 2-5), millers were forced to consider insect sanitation. The danger in the flour moth, sometimes called the "gray plague of flour mills," does not lie so much in food values actually consumed as in the enormous quantities of silken threads spun by its larvæ in and about mill machinery. This webbing habit causes the flour in passing through the machinery to form in ever-increasing clumps or webbed masses, which sooner or later choke or clog the machinery, and necessitates extensive mill shutdowns for cleaning and application of control measures.

Experimental and practical demonstration work has proved the dependability of methods of control under certain conditions. These are fumigation with hydrocyanic-acid gas and the use of heat. Control by freezing (p. 39) is less satisfactory. Smudges, as compared with fumigation with hydrocyanic-acid gas or the application of high temperatures, have only a temporary value. Preventive measures, including cleanliness, are of the greatest value in reducing losses due to insects. Dependence upon natural control by parasites is not advocated. The heat method is recognized as the most effective, practical, and inexpensive of all treatments and has the added advantage of being absolutely safe. Where remedial measures must be applied in mills of moderate size, it has been estimated that the heat method is enough cheaper to pay in five years for the cost of the installation of enough radiation surface properly to heat the mill.

Neither fumigation with hydrocyanic-acid gas nor the use of high temperatures, as recommended for mill-insect sanitation, injures the mill building or equipment or affects the baking qualities of flour.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 873



Contribution from the Bureau of Markets
GEORGE LIVINGSTON, Chief

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THE SHRINKAGE OF MARKET HAY.

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INTRODUCTION.

There is a widespread misunderstanding regarding the so-called loss caused by shrinkage of hay. The Department of Agriculture is constantly receiving requests for definite statements as to the extent of this loss under various conditions, and for methods of curing and storing hay which will tend to prevent loss by shrinkage. Most of these inquiries come from those who want data on shrinkage or loss after the hay has been put into the barn or stack. A few, however, wish to know how much shrinkage takes place from the time hay is cut until it is sufficiently cured to be removed from the windrow or cock. Those interested in shrinkage are hay growers, country shippers, city receivers, commission men, brokers, and consumers in nonproducing territories.

Any request from the producer for data on this subject immediately and naturally suggests this question: "Why should the hay grower, in general, worry about *loss* due to shrinkage?"

The answer is that the farmer believes that a substantial loss usually occurs when hay is stored in the barn or stack, when, as a matter of fact, ordinarily there is no loss of feeding value, and properly no loss in market value. (For a definition of market hay as discussed in this bulletin see p. 30.)

Those who have been accustomed to regard all kinds of field-cured hay as marketable hay at the time it is stored and the loss of water as a real loss will be interested in the following report on some experiments conducted at the Kansas Agricultural Experiment Station in 1904:

Occasional reports have appeared in the agricultural press of the Middle States advocating the baling of clover hay while in a wilted or partially cured condition, claiming that the method was an economical practice, and that it made a better grade of hay than could be made in the ordinary way. These reports have led to considerable discussion among western farmers and in the farm papers as to whether alfalfa could be profitably handled in the same way. In order to determine at what stage of curing alfalfa may safely be baled, and whether this method of handling the crop is a practical one, the Farm Department conducted the following experiment last season:

The baling was done July 16 with a 14 by 18 * * * [two-horse] hay press * * *. This press has a capacity of 1 ton or more of prairie hay per hour. The alfalfa used was the second cutting of medium growth, from an old field, and was about one-fourth in bloom when cut. Fifteen bales were made from green alfalfa, which was raked and hauled to the baler immediately after being mowed. Six bales were made from alfalfa that was wilted, having been mowed in the morning and baled in the afternoon of the same day. Fourteen bales were made from alfalfa that was cut July 14 and put in cocks July 15. This alfalfa was in the "sweat" when baled, and did not differ much in moisture content from the wilted alfalfa. Nineteen bales were made from well-cured hay in proper condition to stack.

TABLE XVI.—*Giving data on baled alfalfa.*

Stage of curing when baled.	Average weight of bales at baling.	Average dry weight of bales Oct. 12.	Loss of weight.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>
Green.....	164	57	65.2
Wilted.....	167	92	44.9
In sweat.....	171	96	43.9
Well cured.....	81	76	6.2

Baling green alfalfa was hard work for the men and teams, and was also a strain on the press. The cured hay handled much easier and baled faster. It will be observed from Table XVI that the average weight per bale of the cured alfalfa, when baled, was 81 pounds, while that of green alfalfa was 164 pounds, and the wilted 167 pounds. The wilted alfalfa was pressed tighter than the green alfalfa. The men who did the baling were inexperienced in the work and were able to make about twenty 3-foot bales in an hour from the green alfalfa. About one and one-fourth hours were required for making the same number of bales of the wilted alfalfa. The capacity of the baler was not tested in the dry alfalfa, but 10 tons per day of 10 hours would represent about the average capacity of the press.

The bales of alfalfa were stored in an open shed and placed on edge in single vertical tiers, a space of 6 to 10 inches being left between the tiers to allow a free circulation of air. The uncured alfalfa was examined at frequent intervals, and notes made on its condition of curing. It had developed considerable heat within 24 hours after baling, and the fermentation lasted about 25 days. The outsides of the bales which were exposed to the air were not at any time very warm, but the interior was very much heated. On October 12 the alfalfa bales were weighed and examined. All of

the hay was found to be well dried. The bales from the green alfalfa were very light, and the wires were so loose that the bales could scarcely be handled. There was no good hay in any of these bales, and not much that would be eaten by stock. Much of the hay was covered by a white mold, and some of it seemed to be partially rotten. The hay which was baled when wilted and that baled from the cock was about of the same grade, and but little better in quality than the hay which was baled when green. The heavier and more closely pressed bales contained the best hay, but none of it was salable hay, and the best of it was inferior for feeding. The hay which was baled after being cured was seemingly as good a grade of hay as when baled, and just as good as if it had been stacked. It had a good color and the leaves were well retained. It would grade No. 1.

It may be concluded from this experiment that it is not advisable to bale alfalfa except when it is well cured and dry enough to stack * * *. (Kansas. State Agricultural Experiment Station. Bul. 123. March, 1904. Pp. 230-232.)

In this experiment an attempt was made to bale and market alfalfa in different stages of curing. The interest centers around the baling of hay when wilted and also in the sweat. It was found that such hay spoiled in the bale and was not even fit for feeding. The loss by shrinkage in the bale amounted to about 45 per cent, which was about the same as the loss in experiment 1, page 4. Thus it will be seen that it is an error to class such material as hay and to regard loss of water as causing a loss to the producer. The experiment also bears out the view that hay can not be classed as hay unqualified, until it has passed through the "sweat" which is the final stage of the curing process. It will be of interest to note that the hay which was well cured and in condition to be baled lost only 6.2 per cent of water when stored so that the air could circulate freely between the bales.

Commercial dealers in hay, on the other hand, sometimes sustain actual money losses on account of shrinkage, as, for example, when partially cured hay, containing more than the normal percentage of water, is delayed too long in transit, or when it is held for a considerable length of time in storage. If such hay is kept moving rapidly through the successive steps of marketing any loss that may be entailed by shrinkage will be so distributed that it will not seriously affect anyone, except, perhaps, the consumer. Even the latter does not lose if he buys by the bale rather than by weight.

Cases in which serious loss is entailed by shrinkage are the exception. Heavy shipments of "new" hay do not usually appear on the market until after the process of shrinkage is practically over; indeed, hay is not customarily classed as marketable until it is thoroughly cured; that is, until it has almost ceased to shrink. Thus it appears that no one has any real reason to feel seriously concerned over the question of shrinkage, least of all the producer.

As a matter of fact, however, a great many persons believe this question to be a vital one. All farmers know, of course, that if 100 tons of hay, for example, is put into the barn early in July, there may be a considerably smaller tonnage there three or six months later. (See experiment 6, p. 5.) In some instances there may be only 80 tons or even less when it is baled or weighed out several months later. Many hay growers have been led to believe that, in a case like this, a positive loss has been sustained of about one-

fifth of the tonnage harvested. If it were true that an actual loss of nutrients takes place, there would be good reason for the hay grower to become alarmed and seek information that will enable him to prevent it. That the department is often asked to furnish data regarding methods of curing and storing hay which will tend to prevent shrinkage is evidence that many farmers believe that the question of shrinkage is a serious one.

Some farmers make a practice of weighing newly made hay just before it is put into the barn and wish to know the amount of shrinkage that will take place, under average conditions, in order to be able to estimate the amount of hay there will be after the shrinkage has ceased. This knowledge is desirable when estimating the quantity of hay that is needed on the farm or the quantity that can be sold at some later date. Buyers and shippers of hay often buy hay baled from the cock or windrow and then hold it for some time before selling it. A general knowledge of the question of shrinkage would be of value to them.

It is the purpose of this bulletin (1) to give data on the average water content of several kinds of hay at harvest time, (2) on the loss of water and dry matter during the curing process, (3) on the loss during the time the hay is stored, and (4) to point out when shrinkage in hay is an actual loss and whom this loss affects, and when the apparent loss is not a real loss, but is simply a natural result of the normal curing process that all good hay must undergo.

RÉSUMÉ OF DATA ON SHRINKAGE.

During the past 30 years many experiment stations have conducted experiments to ascertain the loss occurring in hay when stored for varying lengths of time in the barn or stack. The following selected data, arranged in order of decreasing percentages of loss reported, show what has been accomplished in trying to ascertain the rate of shrinkage in hay:

(1) The largest loss due to shrinkage is reported by the Pennsylvania station.¹ Two plots of clover, not adjoining, were cut at each of three periods of growth, (1) the clover heads in bloom, (2) partly dead, and (3) nearly all dead; the dates of cutting were June 22, July 3, and July 19. The hay was weighed when put into the barn, and then reweighed five or six months later, in order to determine the weight of the "dry" hay. The hay cut in bloom lost 42.2 per cent, that cut when partly dead lost 44.2 per cent, and that cut when heads were all dead lost 25.7 per cent.

(2) At the Missouri station² a stack of second-growth clover, weighing when put up in July 6,514 pounds, shrank in weight by the following March to 4,548 pounds, a loss of 30 per cent.

¹ Pennsylvania State College, Report for 1886, pp. 271-276.

² For report of experiment see Michigan, State Board of Agriculture and Experiment Station, 1901, p. 287.

(3) At the Pennsylvania station (see footnote¹, p. 4) the average shrinkage of early-cut timothy hay (in bloom and stored in the barn) was 25.7 per cent and of the late-cut timothy (nearly ripe) 18.8 per cent; varying in the former case from 14.9 per cent to 36.5 per cent and in the latter case from 15 per cent to 23.4 per cent. The average loss for all cases during two years was 22.2 per cent.

(4) At the Arizona station³ in 1906 the third crop of alfalfa from the entire farm was cut and the stack completed about July 20. This stack contained 23 tons and 1,796 pounds. The stack was sold December 14 and at that time contained 17 tons of first-class hay and 2,825 pounds of poor hay, or a total of 18 tons and 825 pounds—a shrinkage of 5 tons and 971 pounds, or 23 per cent.

(5) At the Michigan station (see footnote², p. 4) on August 31 and September 1, 1896, 6,110 pounds of hay were put into the barn, made from clover sown in the spring of 1896. The growth had been succulent, but the hay was well cured. On February 6 following, during a period of damp weather, it was taken out and weighed and found to have lost 22.6 per cent. A portion of it was musty when reweighed.

(6) This station also reports² a similar loss with timothy hay. In the summer of 1887, 130.5 tons of timothy, in good condition, were put into the barn. The following January 100.5 tons were baled. The chaff, dirt, and short hay from under the press amounted to 1.5 tons. This indicates a shrinkage of 28.5 tons, or 21.7 per cent.

(7) Wale⁴ found that the shrinkage of meadow hay in the stack several months amounted to 17.33 per cent. Clover hay stacked for several months lost from 15 to 17 per cent.

(8) A stack of alfalfa hay, containing 19,372 pounds, was made at the Colorado station⁵ June 15, 1899. The following February it contained 15,904 pounds, a loss of 3,468 pounds, or 17.9 per cent.

(9) At the Utah station⁶ a ton of timothy hay was weighed and placed in the barn July 20. On April 20, nine months later, it weighed 1,686 pounds. The loss amounted to 15.7 per cent.

(10) At the Kansas station⁷ a bag of millet hay was buried in the mow from July 21 until the following March. The loss during the eight months amounted to 14.25 per cent.

(11) At the Michigan station⁸ on July 6, 1898, 5,763 pounds of Mammoth clover hay that had been fairly well cured the day before,

² For report of experiment see Michigan, State Board of Agriculture and Experiment Station, 1901, p. 287.

³ Arizona Agricultural Experiment Station, Eighteenth Annual Report, 1907, p. 224.

⁴ Journal South-Eastern Agricultural College, Wye, No. 18, 1909, pp. 52-53.

⁵ Colorado Agricultural Experiment Station, Bul. 57, 1900, p. 7.

⁶ Utah Agricultural Experiment Station, Fourth Annual Report, 1893, p. 36.

⁷ Kansas Experiment Station, First Annual Report, 1888, pp. 117-121.

⁸ Michigan State Board of Agriculture and Experiment Station. Annual report, 1901, p. 286-287.

kept in the heap overnight in the field, and hauled to the barn at 9 a. m., was stored in one of the large bays in the station barn. The hay had been very dry when raked. On February 18, 1899, the hay weighed 5,117 pounds, showing a shrinkage of 646 pounds, equivalent to 11.2 per cent in 7 months.

(12) Investigations made at the Kansas station⁹ led to the conclusion that, as stacked, well-cured alfalfa will contain from 16 to 24 per cent of moisture, fully air-dried hay from the stack or mow should contain 10 to 12 per cent of moisture, and the average shrinkage of well-cured alfalfa hay put into the stack or mow, by loss of moisture, should not be greater than 10 per cent.

(13) At the Missouri station¹⁰ 5,678 pounds of timothy was stacked as drawn from the field. When weighed the following spring, it had shrunk to 4,972 pounds, a loss of about 12.7 per cent.

(14) At the Kansas station (see footnote 7, p. 5) orchard grass hay lost 9.01 per cent and bluegrass hay lost 10.05 per cent in the mow in 6 months.

(15) At the same station (see footnote 7, p. 5) a bag containing prairie hay buried in the mow for 6 months lost 7.33 per cent.

(16) At the Michigan station (see footnote 8, p. 5) on June 27, 1896, 5 tons of very dry timothy was drawn from the field and, after weighing, was placed in the barn in a mow, separated from the rest of the hay in the barn. It was, later, temporarily covered with grain in the straw. Six months later, on January 26, it was removed and found to have lost 684 pounds, or nearly 7 per cent.

(17) At the Kansas station (see footnote 7, p. 5) a mixture of orchard grass, clover, and a little timothy, buried in a bag in the mow for 6 months, lost 5.71 per cent.

(18) At the Michigan station (see footnote 8, p. 5) in July, 1897, 1,100 pounds of clover hay, containing a little timothy, was put in the barn directly from the windrow, being unusually dry for hauling from the field. It was reweighed November 12 following, when it showed a loss of but 398 pounds, or 3.6 per cent.

(19) At the Utah station (see footnote 6, p. 5) a ton of clover hay put in the barn July 15, 1892, and removed April 20 following, lost 75 pounds, or 3.75 per cent.

(20) At the Kansas station (see footnote 7 p. 5) three tests with prairie hay buried in the mow for 6 months showed that the loss amounted to about 3.50 per cent.

(21) At the same station (see footnote 7, p. 5) one bag of prairie hay, buried in the mow for 6 months, lost only 0.58 per cent. In another case the loss amounted to but 0.29 per cent.

⁹ Kansas Agricultural Experiment Station. Bul. 155, 1908, p. 258-259.

¹⁰ Michigan State Board Agriculture and Experiment Station. Annual report, 1901, p. 286-287.

GAIN IN WEIGHT IN HAY IN THE STACK AND BARN.

In some of the experiments carried on to determine the rate of shrinkage occurring under average conditions, it was found that instead of a loss there was a decided gain in weight in hay in the barn and stack during several months. The results of some of these experiments are as follows:

(22) At the Kansas station (see footnote 7, p. 5) a bag of prairie hay buried in a mow of hay for 4 months gained 0.4 per cent.

(23) A bag of clover hay, at the same time, gained 3.17 per cent in 4.5 months.

(24) Gains have also occurred when large amounts of hay were used in experiments. At the Utah station (see footnote 6, p. 5) 4,565 pounds of timothy hay was stacked on July 20, 1892. On April 21, 9 months later, the hay was weighed and found to have gained 70 pounds, or 1.5 per cent.

(25) Again, at the same station (see footnote 6, p. 5), 4,090 pounds of clover was stacked on July 15, 1892, and the following April the hay weighed 4,528 pounds, showing a gain of 438 pounds or 10.7 per cent.

DATA NOT CONCLUSIVE.

In evaluating the results of these experiments two outstanding facts must be taken into consideration. The first is the wide and seemingly unexplainable variation in the percentages of loss due to shrinkage. The extreme loss, experiment 1, amounts to 44.2 per cent. The losses found in the other experiments gradually decrease until a minimum loss of only 0.29 per cent is found in experiment 21. Experiments 22 to 25 show actual gains in weight, varying from 0.4 to 10.7 per cent. In other words, the extremes show a range of gain and loss amounting to 55 per cent from the time the hay was taken from the field until it was well cured in the stack or barn.

The second fact to be considered is the lack of data concerning the manner in which the experiments were carried out. There are practically no data on the methods used in curing the hay or the treatment the hay received up to the time it was removed from the field. In order to interpret or understand the results secured in a shrinkage experiment it is necessary to note carefully every factor that may have a bearing on shrinkage. These are the factors that every good hay-maker observes and makes allowances for, more or less, when making hay, such as condition of the weather, presence or absence of dew, temperature, clouds, wind, humidity, all factors which bear on the rapidity of curing; the yield, whether light or heavy; the use of the tedder to accelerate curing; length of time the hay is in the swath, windrow, bunch, or cock; time of day the hay is put into the barn or stack; and water content of the hay when stored.

When data on these vital factors are included along with the results of a shrinkage experiment, the loss or gain in weight, whether it be large or small, at once becomes easy to interpret and will be found to be in accord with the natural laws that govern the curing of hay.

Many shrinkage experiments have been made without determining the water content, either at the time the hay was taken from the field or at the end of the experiment. (See experiments 2, 4, 5, and 6.) The hay was merely weighed when put into the barn or stack and again at a specified later time and the amount of loss by shrinkage was determined by the difference between the two weights. It is the publishing of the results of such experiments, especially when a comparatively large loss occurred, that has led many hay growers to believe that an actual instead of an apparent loss takes place when hay is in storage for some time.

This belief has been further strengthened, in some instances, by statements to the effect that besides the loss of water there has been a loss of dry matter, because of fermentation (the amount of which, however, is unknown) without giving adequate evidence to show that any such loss has occurred or even that conditions were favorable for fermentation.¹¹ The loss of dry matter will be discussed later.

FACTORS AFFECTING DETERMINATION OF SHRINKAGE.

FIRST FACTOR—WATER CONTENT WHEN CUT.

There is a great difference in the amount of water contained in grasses and legumes when cut, while curing or being made into hay, and after becoming well-cured hay. A knowledge of the normal water content of hay in these various stages will throw light on what may be expected to happen during the final stages of curing. Table I, compiled from Henry's Feeds and Feeding, shows the average water content of different kinds of hay, as determined by a long series of tests.

TABLE I.—Water content of "unwilted" hay.

	Average.	Minimum.	Maximum.	Difference between extremes.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Timothy, at different stages.....	61.6	47.0	78.7	31.7
Redtop, in bloom.....	65.3	51.5	76.2	24.7
Red clover, at different stages.....	70.8	47.1	91.8	34.7
Alsike clover, in bloom.....	74.8	72.3	77.3	5.0
Alfalfa, at different stages.....	71.8	49.3	82.0	32.7
Cowpeas.....	83.6	72.8	93.1	20.3
Soy beans.....	75.1	63.6	81.5	17.9
Johnson grass.....	61.0	51.1	70.8	19.7
Barley.....	76.8			
Oat.....	73.9			
Rye.....	78.7			
Wheat.....	72.6			

¹¹ Utah Agricultural Experiment Station, Third Annual Report, 1892, p. 47-48. U. S. Department of Agriculture, Bulletin 353, 1916, p. 6, 17.

Forage plants contain comparatively large amounts of water at harvest time. The average water content of timothy, redtop, Johnson grass, and other grass hays is from 60 to 70 per cent. The water content of alfalfa, clovers, cowpeas, etc., is somewhat higher, ranging from 70 to a little more than 80 per cent. The maximum water content of hay plants occurs, not at harvest time, but when they are young and are growing vigorously. As the plant approaches maturity its water content is gradually lessened,¹² because the growing has almost stopped and the plant requires only sufficient food to mature its seed. The minimum water content is found at this stage.

There is a rather wide difference between the maximum and minimum water content of grasses and legumes at the time they are cut for hay, depending largely on the length of the harvest season, which sometimes exceeds three weeks. Hay cut at the earliest possible date will have a much larger water content than that cut at the end of the haying season. The variation in the quantity of water in timothy cut at these two extremes amounts to almost 32 per cent. (See Table I.) A slightly greater difference is found in some of the legumes, clover and alfalfa, for example.

This great variation in the quantity of water in hay when cut is alone ample cause for a considerable difference in the amount of shrinkage that occurs in the barn or stack. This is the first important factor that influences shrinkage of hay. In actual practice it frequently happens that hay cut at the end of the haying season is more thoroughly cured than that cut at the beginning of the season, because the late-cut hay will lose a greater percentage of its total water content in a given length of time, other things being equal, than will early-cut hay "full of sap." Therefore it is obvious that there may be a considerable difference in the water content of two lots of hay when they are removed from the field and, consequently, a difference in the amount lost by shrinkage. The water content of field-cured hay varies considerably, as is shown in Table II.

¹² See Utah Agricultural Experiment Station Bul. 48, 1897. Alfalfa or lucern for water content of alfalfa from May 4, when plant was $6\frac{1}{2}$ inches high, until August 24, when leaves were dry.

U. S. Department of Agriculture. Bul. 353, 1916.

TABLE II.—*Water content of field-cured and well-cured barn and stack-cured hay.*¹

	Field-cured hay.	Well-cured barn or stack hay.		
	Maximum.	Minimum.	Average.	Difference between minimum and maximum water "content."
	Per cent.	Per cent.	Per cent.	Per cent.
Timothy (all analyses).....	28.9	6.1	11.6	22.8
Timothy, early to full bloom.....	28.9	7.0	12.8	21.9
Timothy, late bloom to early seed.....	21.6	7.0	14.1	14.6
Redtop (all analyses).....	² 28.0	6.8	9.8	22.2
Redtop, in bloom.....		6.8	8.0	
Alsike clover.....		5.3	12.3	
Alfalfa (all analyses).....	30.0	4.6	8.6	25.4
Red clover (all analyses).....	31.3	6.0	13.0	25.3
Cowpea.....		7.6	9.7	
Soy bean.....	20.0	6.1	8.6	13.9
Johnson grass.....			10.1	
Barley.....	15.0	6.4	10.0	8.6
Oat.....	26.5	9.5	12.0	17.0
Rye.....			8.1	
Wheat.....			8.1	
Prairie.....	17.1	6.5	10.0	10.6

¹ Taken from U. S. Department of Agriculture Farmers' Bulletin 22, 1901, Henry's Feeds and Feeding, 16th edition, and various experiment station reports.

² Estimated.

SECOND FACTOR—MAXIMUM WATER CONTENT WHEN STORED.

Available experimental data and the experience of practical hay makers establish the fact that there is a wide variation in the amount of water in hay when put into the barn and stack. This is the second important factor bearing upon the percentage of shrinkage in hay. The highest recorded percentages of water in hay when put into the barn and stack (see Table II) show that the average maximum for timothy, alfalfa, and red clover is about 30 per cent, timothy 28.9 per cent, alfalfa 30 per cent, and red clover 31.3 per cent. It is not known under what conditions hay with a 30 per cent water content will cure out properly, or whether the safe maximum is higher or lower than this amount, since here again there is a lack of definite data that would be of utmost value to the haymaker. No systematic experiments have been made to determine the maximum water content that field-cured hay may have without subsequent injury by heating.

It is safe to assume that the three lots of clover used in experiment 1 (p. 4) contained considerably more than 30 per cent of water. Their losses by shrinkage were 42.2, 44.2, and 25.7 per cent. If these lots when cured contained the average amount of water found in good barn-cured hay (13 per cent), it follows that they contained 49.7, 51.4 and 35.3 per cent of water, respectively, when put into the barn. It is not known whether the hay in these experiments cured out properly or was spoiled because of the high water content, but in

one case (experiment 5, p. 5) clover hay, which lost only 22.6 per cent by shrinkage, was partly musty at the end of the experiment. Considering that the normal water content of cured hay amounts to 13 per cent, the percentage of water in this particular lot at the time it was put in the barn was 32.66 per cent.

The Kansas station ¹³ has found that alfalfa containing as much as 24 per cent of water will cure out properly in the stack. In the semiarid West it may be safe to stack hay containing more than 24 per cent of water, while in the South and parts of the East, where the humidity is greater and unfavorable weather often prevails, it may not be safe to put up hay with such a large water content.

THIRD FACTOR—NORMAL WATER CONTENT WHEN CURED.

The normal water content of cured hay is the third important factor to be taken into account. Shrinkage in hay practically ceases when the water content reaches a certain point which varies with climate (See "Average," Table II), and not until then is the curing process finished in barn or stack hay, which may then be rightly classed as well-cured, marketable hay. As the water content of hay baled from the windrow or cock is sometimes above normal, it is subject to shrinkage in the bale. The average normal water content of hay is the amount of water usually contained in hay after it has passed through the "sweat" or "heat" in the stack or barn and is ascertained by averaging all available water-content analyses. In the case of timothy (see Table II), 221 water analyses have been averaged, giving an average of 11.6 per cent. In the cases of other hays fewer analyses are available, which probably accounts, in part at least, for the variation in the figures presented as representing the average water content of the different grass and legume hays.

FOURTH FACTOR—MINIMUM WATER CONTENT.

Sometimes hay becomes very dry. In fact, in the West "dry" hay is discriminated against on account of the loss by shattering and because it is thought to lack palatability. The water content in "dry" hay is shown in Table II, under "minimum." When the percentage of water in hay is so low that the air will no longer absorb any of it, the hay is said to contain a minimum amount of water. The minimum water content which is the fourth factor depends upon the humidity of the air, length of time the hay is exposed to such air, and the amount or bulk of hay in the stack or barn.

To lower the natural minimum it is necessary to subject the hay to artificial drying, as is done in the laboratory when making a determination of dry matter. The figures given in the table do not imply

¹³ Kansas Agricultural Experiment Station, Bull. 155, 1908. pp. 253-259.

that hay usually becomes that dry or that the hay grower should expect such a low water content under average conditions. A low minimum water content is reached naturally only during very unusual conditions, such as a long exposure in a very dry and hot climate like that found in the Southwest. Neither should it be expected that the water content, having once reached the minimum, will remain constant, unless the temperature and humidity of the air remain constant, a condition which does not prevail in the larger part of the hay-growing section of the United States for any great length of time.

From the data presented it is shown that the minimum water content of timothy is 6.1 and of alfalfa 4.6 per cent. The minimum for the other kinds of hay is slightly higher—the average for all being 6.52 per cent. If the average or normal water content figures are averaged for all of the hays for which the minimum has been figured, it is found that hay, in general, contains about 10.32 per cent of water when well cured. The difference between the two averages is 3.6 per cent.

FIFTH FACTOR—ATMOSPHERIC HUMIDITY.

The water content of cured hay in the stack, barn, or bale is subject to fluctuations, caused by changes in atmospheric humidity which is the fifth factor to be considered. If hay contains a larger percentage of water than does the air there will be a loss by evaporation. If the hay is drier than the air it will absorb water. A change in humidity affects a small quantity of hay to a relatively greater extent in a given time than it does a large bulk.¹⁴

Oat hay was baled on June 1, 1913. The average loss during July and August, when the weather was unusually dry and hot, amounted to 1.4 per cent. Small samples, weighing 44.5 ounces, taken from the bales and inclosed in cotton bags and suspended under shelter, where the air could circulate freely, lost an average of 4.3 per cent during the same period. Again, on June 1, 1913, four large bales of oat hay, averaging 243.8 pounds, were made. The loss by August 1 amounted to 9.8 pounds, or 4.02 per cent. During the first 25 days of September there was an additional loss of 3.4 pounds, or 1.4 per cent. From September 25 to December 1 there was a gain of 1.4 per cent, which brought the weight back to 234.1 pounds, the weight on August 1.

Experiments with small bales of oat hay made the following year (1914–15) showed a much larger proportional fluctuation. The bales weighed, on an average, 178 pounds, or one-third less than the large bales used the year before. The small bales, baled on June 1, 1914, had lost 8.1 per cent by August 31. From that date until February 25, 1915, they gained a total of 5.9 per cent, making the net loss from June 1 to February 25 but 2.2 per cent. The loss was attributable to the dry weather during July and August, and the gain to the wet weather during the winter months.

It should not be inferred, from the results of experiments to date, that hay in small bales will always lose more by shrinkage, or that their normal water content will be subject to a greater degree of fluctuation than that of hay in large bales. Information is lacking on the one

¹⁴ U. S. Department of Agriculture, Bull. 353, 1916. p. 32.

practical point of interest to the hay maker and shipper—that is, the manner in which the bales were stored during the experiment. If they were stored separately, cross piled, placed on the top or outside of a pile, or in a small pile by themselves, then the small bales would naturally be influenced by weather conditions to a greater extent proportionally than would large bales. If baled hay is stored flatwise—that is, the bales resting on their sides and no air space allowed between, then there should be practically no difference in the amount of gain and loss due to changes in the weather, etc., between hay in large bales and hay in small bales, provided the degree of compression were the same.

Reactions from changes in the weather do not affect the entire mass of hay quickly unless the bulk is small. In large mows and stacks the hay in the interior is more or less protected by the top and side layers of hay; consequently it loses water slowly without being affected by exterior changes in humidity. The center of the stack often dries out much more slowly than the top and bottom. The Colorado station¹⁵ found a difference of 10.3 per cent in the amount of water lost by different parts of stacked alfalfa hay. A large stack of well-cured alfalfa was put up June 15, being divided into four layers by slats. On February 12, eight months later, the loss of the different layers was found to be as follows: Bottom layer 17.6 per cent, third layer 17 per cent, top layer 23.8 per cent, and the second layer only 13.5 per cent. Experiments by Wale¹⁶ also show a greater loss by shrinkage in the top layers of stacked hay than in the lower layers.

These experiments explain why hay that is baled after having passed through the sweat sometimes loses weight by shrinkage. The loss of water occurs in the hay taken from the middle of the stack, where it has been insulated by the hay on the outside.

It is not definitely known to what extent the degree of atmospheric humidity influences the water content in well-cured hay in the barn or stack. The data indicate that, under average conditions, the water content will vary with the weather from 2 to 4 per cent below normal, to about the same amount above normal. There is need for a number of carefully conducted experiments to determine the extent of gain or loss of cured hay in storage.

The loss by shrinkage of well-cured hay during dry weather is, in time, offset by the gain in weight during wet weather, although, in individual cases, shrinkage may cause a loss to the producer or shipper. In various hay-growing sections the high price of hay during the summer months (see p. 26) more than makes up for any loss caused by low water content.

¹⁵ Colorado Agricultural Experiment Station, Bull. 57, 1900. p. 6-10.

¹⁶ Journal Southeastern Agricultural College, Wye, No. 18. 1909. p. 52-53.

SIXTH FACTOR—EFFECT OF TIME ON SHRINKAGE.

The sixth factor in the shrinkage of hay is that of time. The time factor is not nearly as important as it would seem to those who have not given the matter careful consideration. A study of the 25 experiments given on pages 4 to 7 will show that, in general, there is no correlation between percentage of loss and lapse of time, as affecting hay in the barn or stack. In other words, the amount of loss that may occur during three months has absolutely no mathematical relation to the amount occurring during six months, nine months, etc. The average loss by shrinkage in the 25 experiments amounted to about 16 per cent. The average length of the experiments was about six months, the shortest experiment lasting four months and the longest about nine months. The average loss of weight in these experiments has no significant relation to average time. (See rule for measuring shrinkage, p. 21.) The relation of time to amount of shrinkage of barn and stack hay is significant only during a comparatively short period, that is, while the hay is going through that part of the curing process commonly known as "sweating" (heating and fermentation), which lasts from three to six weeks, or perhaps a little longer. While this process or change is taking place in the stack or mow, the greatest reduction in water content also takes place, and very soon after sweating ceases the hay will be found to contain its normal percentage of water. The amount of shrinkage that takes place after the first month or two is comparatively small, and humidity or condition of the weather becomes a much more important factor than does that of time. The factor of time is important, however, while hay is curing in the field, in that it affects shrinkage later on.

SHRINKAGE OF NEWLY MOWN HAY.

It has been pointed out (see Table I) that newly-mown hay contains a large amount of water, and that about three-fourths (see Table II) of the water must be "cured out" in the field before hay is ready to be put into the barn or stack, if it is desired to make first-class hay. The prime question regarding shrinkage is not how much hay will shrink from the time it is cut until it can be stored, but how much the haymaker should allow hay to cure in the field. During ideal hay-making weather hay loses water rapidly and in a comparatively short time, if not handled properly, will lose as much as 90 per cent or even more of its water content, becoming so dry that there will be no further loss by shrinkage in the stack or barn. When this happens there is liable also to be a decided loss of color, and with legume hay there may be a large loss of leaves by shattering when the hay is handled.

Experiments¹⁷ made in California showed that, in one instance, alfalfa cut at 10.22 a. m. lost 39.1 per cent of the water in an hour and a half, and that by 4 p. m., about 6½ hours later, it had lost 63.7 per cent of its total water content. Timothy, in Ohio, lost 30.4 per cent of water from noon until 5 p. m., when the temperature at noon was but 76° F., indicating that the conditions were not very favorable for curing.

The Iowa station¹⁸ found that different plats of alfalfa cut and hauled on the same day may vary as much as 20 per cent in shrinkage, the hay handled early in the day possibly containing twice as much moisture as that hauled in the afternoon.

A comparatively small difference in the length of time hay remains in the field, in the swath, and in the windrow after it has cured sufficiently to be stored may make a decided difference in the amount lost by shrinkage in the barn or stack.

At the Utah station¹⁹ two lots of clover hay put up the same day showed a difference of 14.45 per cent after being stored nine months. The hay stored in the barn lost 3.75 per cent and that stacked gained 10.7 per cent.

The knowledge which enables the farmer to tell when hay has lost just enough water to make it safe to put it into barn or stack is valuable and indeed essential, while a knowledge of the exact percentage of shrinkage that takes place during field curing is neither necessary nor helpful to the average haymaker.

LOSS OF DRY MATTER.

A part of the so-called loss in hay, through shrinkage, is sometimes due to an actual loss of dry matter. The accepted usage of the term "lost" to denote both loss in water content and a reduction in the amount of dry matter in hay after being in storage for some time is somewhat misleading. It is quite proper and self-explanatory to say that hay has lost a part of its water content, for this is exactly what has happened—the water has actually been taken out of and away from the hay. But when it is said that there has been a loss of dry matter during the shrinkage of hay, the impression may be given that the dry matter is also carried out of and away from the hay. As a matter of fact, dry matter is "lost" in a more roundabout way than is water, which evaporates whenever the percentage of water in the air is lower than that in the hay. Furthermore, once gone, dry matter can not return, as water may.

Water is a comparatively simple compound and readily changes in form as the temperature of the air varies. The dry matter of hay,

¹⁷ U. S. Department of Agriculture Bull. 353, 1916. p. 28-30.

¹⁸ Iowa Agricultural Experiment Station Bull. 137, 1913. p. 57-58.

¹⁹ Utah Agricultural Experiment Station, Fourth Annual Report, 1893. p. 35-37.

however, is composed of a number of rather complex substances, such as protein, carbohydrates, fats, and fiber, which are not appreciably affected by the changes of ordinary air temperatures, or by time, as limited by the length of time hay is usually in storage.

If the term "destroyed" were used in place of "lost" it might better convey the idea that a loss of dry matter does not take place as easily as does that of water, or at least that the conditions under which it occurs are different. The indiscriminate use of the term "lost" and a lack of knowledge of conditions under which dry matter may be destroyed seem to have led some to assume, in certain instances at least, that dry matter has been destroyed when conditions do not warrant such an assumption.

The primary cause of loss of dry matter in hay is improper or insufficient curing of the hay before it is put into the barn or stack. Hay that contains too much water, either because it has not been sufficiently cured in the field or because it has been wet by rain, is liable to lose a part or even most of its dry matter later on. The loss of dry matter is not due merely to direct loss of water, as is sometimes supposed, but largely to conditions arising from the mistakes or misfortunes of the haymaker. Hay is stored when insufficiently cured, either because the haymaker uses poor judgment or because he is unable, on account of unfavorable weather, lack of haymaking machinery or help, to cure his hay properly. In such cases as the water content is above the maximum, destruction of dry matter is possible.

When wet or undercured hay is put into the barn or stack it soon begins to sweat and ferment, just as does properly cured hay. The degree of heat engendered in the fermentation of well-cured hay does not injure the dry matter. In the undercured or wet hay the temperature continues to rise until more or less of the hay is discolored, charred, or even burned to ashes. Such high temperatures are engendered primarily by the excess water in the hay, which creates conditions favorable for bacterial growth and chemical action, involving various changes in which heat is produced. In some instances continued cloudy, rainy, or foggy weather, by preventing the evaporation of water from the hay, may render conditions favorable for the destruction of dry matter, a situation which could not arise during dry, sunny weather.

Keable and Wale ²⁰ found that "newly ricked hay (clover), undergoing a natural fermentation, soon reaches its maximum temperature, i. e., toward the end of the first or the beginning of the second week after the hay was put into the rick." It was also found that a second fermentation occurred, beginning about three weeks after

²⁰ Journal Southeastern Agricultural College. Wye. No. 18, 1909, p. 52-55.

the hay was ricked. It was also found that there was a direct relation between temperature and water content of the hay, the highest temperature occurring in the stack that contained the largest percentage of water.

The material for rick No. 1—first-cut clover hay— was in ordinary good condition for stacking, and when cut into in December was found to have undergone a rather low fermentation, being only slightly browned and in good condition.

The material of rick No. 2—second-cut clover hay— was greener when stacked, and as was to be expected, the maximum thermometer readings were somewhat higher than in the case of rick No. 1. The hay produced also showed a deeper brown color, owing to the higher temperature of fermentation.

The highest temperature occurring in the two stacks while undergoing fermentation was between 140° and 150° F. The investigator's conclusions are as follows:

It seems unlikely that any harm to the dry matter will result where the hay has not exceeded a temperature of 150°F. How much higher the temperature may safely rise it is at present impossible to say; so much depends on the size of the rick and the degree of consolidation that has taken place. The less the consolidation the more air there is present, and the higher the temperature is likely to rise. At the same time imperfect consolidation is generally to be found in ricks of small size, but on account of the small bulk more heat is lost by radiation, and hence there is less liability to fire.

According to Hoffman,²¹ the organic matter in hay is destroyed at a temperature of 226° F. or over.

When spontaneous combustion occurs in clover, heat is generated in the hay, oxygen being taken up from the air and the organic matter transformed into carbon dioxid and water. The water moistens the hay, and the moistened material ferments because of the presence of bacteria. The fermentation also produces carbon dioxid and water, as well as small amounts of hydrocarbons, hydrogen, organic acids, enzymes, etc. Heat is also produced from the fermentation. The fermentation is more rapid if the clover is moistened at the beginning. However, the water produced by the oxidation of the material is sufficient to start it. The fermentation of the hay causes the temperature of 133° F. At this temperature a more violent oxidation takes place and the temperature rises to about 194° F. Other processes then take place which char the material and cause a slow rise in temperature to 226° F. When this temperature is reached, the hay rapidly heats and the charring proceeds rapidly. All these processes destroy at least half of the material. Theoretically the temperature may reach 374° F.

According to the tests made, clover hay may become ignited at 302° F. to 392° F. Therefore the temperature may rise sufficiently high to cause spontaneous combustion. Oxygen from the air is essential to combustion.

These experiments confirm the belief that there can be no appreciable loss by destruction of the dry matter in hay in storage when it has been properly cured in the field, provided the hay is protected from injury by rain. In other words, the natural sweating or curing and the resultant shrinkage of hay in the stack or barn do not involve

²¹ Hoffman, F. H., *Zeitschr. Spirit-ind.*, 1897, Nos. 35, 39, 41, 42, 45, 47, 50, abs. in *Biedermanns-Centralblatt für Agriculturchenne*, v. 27, No. 6, 1898. p. 295, 296.

a destruction of dry matter, because such hay does not contain enough water to engender a temperature sufficiently high to injure the dry matter.

It should not be inferred, however, that such loss from well-cured hay in the stack will be no greater than in the same kind of hay in the barn. It is a matter of common knowledge that there is often quite a serious loss when hay is stacked for several months. An unavoidable loss, caused by the action of the sun and rain, is sustained when hay is stacked and left uncovered. The sun bleaches the outside of the stack and rain often causes the hay to discolor or even to rot. The amount of loss in such cases depends largely upon the skill exercised in building the stack, and while the greater part of the loss is caused by discoloration, which lowers the grade and, consequently, the market value, there is also an actual loss of dry matter because of mold and rotting.

Lipscomb²² in 1907 showed that there was a decided loss through discoloration by rain, when hay had been stacked for several months. Two stacks of timothy hay were put up in July. At the end of four months 20 per cent of the hay in one stack was found to be unsalable and fit only for bedding or feed as roughage. There was a loss of about 40 per cent in the other stack at the end of eight months. As a matter of fact, there was, strictly speaking, no great loss of dry matter, but such hay is considered as worthless or lost since it is not marketable.

METHODS OF MAKING HAY TO PREVENT UNNECESSARY SHRINKAGE.

There is no method known whereby hay can be so cured that it will retain, indefinitely, a larger percentage of water than is normally contained in such hay after it has gone through the sweat and is thoroughly cured. The water in hay is not chemically locked up as is the dry matter, and, for this reason, the haymaker is unable to control, except within very narrow limits, the water content of hay after it has once become entirely cured. A knowledge of these facts should not cause the haymaker anxiety, for, as will be shown later, the loss of water or shrinkage does not ordinarily entail a real money loss to him.

It is very important that a close watch be kept on the water content, or rather on the rapidity with which water is being taken from hay while in the various stages of curing in the field, not with a view of checking the shrinkage to take place later in the barn or stack, but because loss by shattering depends upon the dryness of the hay when handled. The more dry hay becomes in the windrow or swath the more it will lose by shattering, and this is a real loss of the most nutritious part of the plant, especially of legumes. Hence, it is highly

²² U. S. Department of Agriculture, Farmers' Bulletin No. 362. 1909, p. 26.

important that the haymaker watch the curing of hay very closely, to note, first, just how long it may lie in the swath without shattering too much when raked into the windrow, and, second, just how soon the water content falls so low that the hay can be stored without danger of spoiling in the sweat. Incidentally another benefit accrues from handling hay at just the proper moment. The hay that has not been allowed to become too dry when stored has the best color. This is an important factor in market hay, for color "sells" hay.

STAGE AT WHICH HAY IS CUT.

The stage of maturity at which hay is cut does not affect the amount of water contained in hay after it has gone through the sweat. The Pennsylvania station²³ conducted experiments for two years to determine the best time for cutting timothy to secure the greatest amount per acre of total nutrients. There was a difference of about 16 days between the early cutting and the late cutting. The average shrinkage of early cut hay (in bloom) was 25.7 per cent and of the late cut (nearly ripe) 18.8 per cent. The amount of shrinkage was determined by weighing the hay, and had the experiment been concluded with merely the weighing, as many others have been, the results would have indicated that it is best to cut timothy late, since there is less shrinkage, about 7 per cent in this instance, than there is in early cut hay. However, after the hay had been weighed, a water analysis was made in each case, which showed that the early cut hay contained an average of 8.94 per cent water and the late-cut hay 8.83 per cent, indicating that the time of cutting has practically no influence on the water content of thoroughly cured hay. Late-cut timothy in reality is inferior to early cut, since the former contains a smaller percentage of total nutrients and is inferior in color to the latter, and hence does not command as good a price on the market.

At the Maine station²⁴ two lots of timothy were cut, one in full bloom and the other 18 days later. The early cut hay lost 16.6 per cent of water in 9 months and the later-cut hay lost 18.1. At the end of the experiment the early cut hay contained 10.4 per cent of water and the late-cut hay 9.7, a difference of only 0.7 per cent.

The results of these experiments indicate that while the percentage of shrinkage of early cut and late-cut hay may vary greatly, the water content of the hay when cured does not vary appreciably with the stage of maturity at which it is cut.

²³ Pennsylvania State College. Report for 1882-86, pp. 271-276.

²⁴ Maine Agricultural Experiment Station, Annual Report, 1890, p. 55-67.

CURING PRACTICES.

The best way to prevent a large shrinkage in stored hay is to get rid of the greater part of the surplus water while the hay is curing in the field. If this is done, the commodity when put into the barn or stack will be good field-cured hay, instead of partially cured forage which must of necessity be subject to a large shrinkage, frequently accompanied by discoloration and destruction of dry matter by heating and other processes.

Detailed methods of curing hay²⁵ will not be given here, but the careful use of the tedder, or of the left-hand side-delivery rake, or both, will, in average haying weather, cause the hay to cure quickly and evenly throughout and thus prevent excessive shrinkage later on.

Heavy yields of mixed timothy, clover, and alfalfa should be tugged soon after cutting and sometimes again before being raked. If hay is left undisturbed in the swath, until it is hauled the top hay appears dry and leads the haymaker to believe that it is ready to haul in. Such partially cured hay will lose considerably by shrinkage in storage. The use of the tedder will cause the hay to cure out evenly. If part of the curing is done in the windrow, the left-hand side delivery should be used, as it throws the hay into loose windrows in such a position that the air has access to it and cures it rapidly. It is safe to rake hay in a greener state when the side-delivery rake is used than with the straight or sulky rake. This is the chief advantage of the side delivery. It is not to be recommended for raking legume hay that cures altogether in the swath, because of the loss of leaves by shattering.

METHOD OF STORING.

If he thinks it worth while, the haymaker may control, to a limited extent, the loss of water from part of his hay at least, by the way in which he stores it. It has already been noted (see p. 13) that when hay is put into large mows or stacks the hay in the interior shrinks more slowly than does that of the top and sides. Water is lost more rapidly from hay in small stacks or mows than from large ones. It would not pay, however, to build large hay barns or stacks merely in an attempt to delay the escape of a comparatively small percentage of water for a short period. The economy of making large stacks depends on such factors as amount of labor required and the method of disposing of the hay, rather than on that of trying to conserve water above the normal percentage found in well-cured hay.²⁶ The practical haymaker does not give the matter of shrinkage any thought in deciding what size to make his stacks, as the labor involved in making a large stack counteracts the saving in shrinkage.

²⁵ See Farmers' Bulletin 943 for information on haymaking.

²⁶ See Farmers' Bulletin No. 1009 for a general discussion of size of stack to make under different conditions.

LIMITATIONS OF RULES FOR MEASURING SHRINKAGE.

If a definite rule for measuring shrinkage could be laid down, it could be used to advantage in all of the hay-growing sections. That there is a need for such a rule is shown by the number of inquiries received by the Department of Agriculture. Such a rule could be used to determine the yield of experimental plots, but its greatest use would be to the hay grower who hauls his hay on wagons to the barn and has easy access to wagon scales, for it would enable him to compute, to the ton, just how much hay he would have for sale after deducting the amount needed on the farm. Again, if he grows hay for the winter feeding of stock, he could easily determine, by using a rule for shrinkage, how much live stock he could keep during the winter. Merely weighing the hay as it comes from the field, on its way to the barn, does not give a significant figure to the average hay grower, since he does not know whether the shrinkage will be 10, 20, or 30 per cent; indeed is not sure that there may not be a gain a few months later.

The Rhode Island station used a rule allowing a 20 per cent reduction in the weight of field cured hay to represent barn-cured hay. This rule was based on the usually accepted idea of practical farmers in that State. In 1902 the actual weights of field-cured and barn-cured hay were taken to check the accuracy of the 20 per cent rule. With one plot there was an error of about 6 per cent, in another about 5 per cent, and in another about 0.5 per cent in total shrinkage. In each instance it was found that a 20 per cent allowance for shrinkage was too great.²⁷

The Kansas station says, in regard to the average amount of shrinkage:

Men experienced in handling hay usually figure on about 20 per cent loss in the weight of the hay after it is put into the mow. The statement is also made that each bale (size and weight not given) will shrink from 2 to 5 per cent in weight.

It appears that the amount of moisture retained in cured hay when stacked varies with different kinds of hay and with different conditions of curing. Ordinarily the loss in the weight of hay stacked when well cured and protected from loss other than that which may occur by natural shrinkage should not be greater than 10 to 15 per cent.²⁸

According to this investigator, hay in the mow loses considerably more by shrinkage than hay in the stack, provided the stack is protected from loss other than that which may occur by natural shrinkage; that is, loss from bleaching and rotting due to exposure to the weather. To prevent such loss it would be necessary to protect the top and sides of the stack, which is exactly what the barn does, and the amount of shrinkage would of necessity be the same in the barn

²⁷ Rhode Island Agricultural Experiment Station Bull. 82, 1902, p. 130-131.

²⁸ Kansas Agricultural Experiment Station Bull. 175, 1911, p. 331.

and protected stack if the same kind of hay (cured to the same degree) were placed in each. There are no experimental data showing that hay in the barn loses more by shrinkage than hay in the stack. In fact, the average loss of the hay stored in the barn, in the data cited on pages 4 to 7, amounted to 14.7 per cent, while the average loss in the stacked hay was 18.6 per cent.

An earlier statement from the same investigator regarding the average amount of shrinkage does not agree with the one just reviewed. In speaking of the shrinkage of alfalfa he says: "The average shrinkage of well-cured alfalfa hay put into the stack or mow by loss of moisture should not be greater than 10 per cent."²⁹ Again: "Men experienced in the handling of hay usually figure on about 20 per cent loss in weight after the hay is put into the stack or until it is sold or baled."

In these instances the implication is that there will be the same amount of shrinkage in the mow as in the stack, and in either case it "should not be greater than 10 per cent." This estimate is about half of the amount of shrinkage figured by men experienced in handling hay in Kansas.

From these and other data presented it will be seen that any general rule for measuring shrinkage would have to allow for such wide variations that it would cease to be a rule, while a rule based on the average amount of shrinkage would be of no value to the individual hay grower.

The shrinkage of hay is influenced by such variable factors as the weather, stage of maturity when harvested, and different methods of curing, and the resulting product varies from half-cured forage to dry-sunburnt hay. What the individual haymaker wants to know is approximately how much hay shrinks when cured by a given method under given weather conditions. For example, the man who lives in a dry, irrigated section and cures his hay in the swath and windrow wants to know the average shrinkage of hay cured under such conditions. Again, those who put their hay into the cock and leave it standing until it is really well cured, want to know how much hay cured in this manner will shrink. The average shrinkage of hay from all hay-growing sections means nothing to the individual. The results of experiments already made show such a wide variation that they are of but little value, if any, to the haymaker in any specified hay-growing section. (See p. 7.)

This being true, how then can the haymaker, who so desires, estimate the shrinkage of his hay? There are two ways of determining shrinkage. First, when the hay is cured in a more or less haphazard manner—that is, when no definite system is used—or when unfavorable weather interferes with the curing, average samples of

²⁹ Kansas Agricultural Experiment Station Bull. 155, 1908, p. 258.

the hay may be taken and a water determination made, as is done in determining the grade of shelled corn. By subtracting the average normal water content of the kind of hay in question from the average found by analysis a fairly accurate estimate may be made. This elaborate process must be repeated every year, and for every field of hay cured under new conditions. The taking of average samples will be found to be no easy matter, and it is doubtful if it will pay, in many instances, to have a water determination made. By the application of the second method it will be possible to establish a definite rule for the shrinkage of hay on a particular farm under given conditions in regions where weather conditions are fairly constant. The conditions under which it will be possible to work out such a rule are: The acreage of hay cut must be comparatively large, so that haymaking is one of the principal farm enterprises; a fully equipped crew, well organized, must be used; and the weather must not be subject to sudden changes.

In the prairie and alfalfa section of the Middle West and West haymaking is often conducted on a rather large scale, day after day, during most of the summer. In a well-organized crew the rakes are kept a certain length of time behind the mowers. The hay always remains about the same length of time in the swath and windrow and it is nearly always cured to about a standard degree when taken from the field to barn, stack, or press. In other words, the hay-making is done in a businesslike and systematic manner, and guess-work is entirely eliminated, so that well-cured hay one day means exactly the same thing as well-cured hay on any other day. Under such conditions it is possible to work out a definite and permanent rule for shrinkage. This can be done by weighing the hay before and after storing or by having water determinations made in a laboratory. The average shrinkage as determined for one year will hold true for following years as long as the system used and the conditions remain the same.

The weather in the East and South is sometimes very changeable, which makes it impossible always to cure hay as desired in the field, so that no shrinkage rule could be worked out that would apply uniformly to hay cured in these regions.

MONEY LOSS CAUSED BY SHRINKAGE.

The grower, feeder, and shipper naturally wish to know whether or not shrinkage causes a direct money loss, and, if so, under what conditions, and whom such loss affects. From a practical or economic standpoint it may be said that shrinkage becomes of importance only when it affects the feeding value or tonnage of hay. In considering such loss shrinkage will here be considered as loss of water only, since

it is the loss of water in most instances, and not dry matter, that has a bearing on the practical side of the question.

Considered purely from a farm-management standpoint, shrinkage in storage always means a certain initial loss to the producer, inasmuch as the handling, hauling, and storing of hay containing an excess of water increases the cost of production by requiring extra labor and time to handle the excess weight. Sometimes this extra cost is more than offset by improvement in the quality of the hay, because it is stored as soon as it is safe to haul, and thus cures out properly in the barn or stack. The extra expense of handling heavy, improperly cured hay that will afterwards spoil by heating, however, is an absolute loss that can not be recovered when the hay is sold or fed.

THE PRODUCER DOES NOT LOSE.

The shrinkage of hay does not cause a direct money loss to the producer who feeds his hay, for the water lost has no actual feeding value, and there is just as great a total of nutrients in a barn of hay after a normal shrinkage has taken place as there was when the hay was put into the barn. In calculating rations, however, it will be necessary to feed a smaller amount of thoroughly cured hay to furnish the required amount of nutrition than when feeding "green" hay (see definition, p. 31) containing an excess of water. For this reason the producer who grows hay for feeding on the farm need not be concerned about the so-called loss from shrinkage.

When hay is grown for the market, shrinkage sometimes involves a money loss under the present system of marketing, though not to the grower. Hay is not graded according to the percentage of water contained, as is corn. Hay containing more than the normal amount of water is often shipped to market. This kind of hay does not always bring top prices, however, for if it is "hot" it may be graded down, until the price not only makes allowance for the excess weight of water contained, but also for the damage (discoloration, etc.) resulting from excessive heating during shrinkage. When hay which has passed through the sweat, but still contains a higher water content than normal is shipped to market, the producer is paid for the extra water therein at the rate paid for the hay itself. This selling of water at the price of market hay is allowable at present, but when a deliberate attempt is made to make and market hay with a water content above normal it very nearly approaches, in theory, at least what may be called "sharp practice."

The hay grower, however, should not be blamed entirely for attempting to avoid what he may think is likely to be an actual loss by shrinkage. In 1882 Jordan³⁰ advocated that the hay grower

³⁰Jordan, W. H. Experiments and investigations conducted at the Pennsylvania State College, 1881-82. p. 7-14. [Unnumbered publication.]

protect himself against loss of water by shrinkage. He assumed that if hay was worth, say, \$10 per ton when cured in the field, the producer should not receive less than this price during the remainder of the year. According to his theory the farmer should advance the price of hay sufficiently from time to time to cover the loss of water. In other words, he advocated that if hay is worth \$10 per ton when made, and loses 24 per cent by winter, the producer should sell it for about \$12.50 per ton.

There are serious practical objections to this theory. In the first place, it is assumed that the price of hay remains stationary during the entire year, which does not happen in practice, since the price varies according to demand, size of current crop, local conditions, etc. Again, the producer does not ordinarily determine the price of hay. This is done in the city markets, and the price of hay sold locally is based, in general, on the quotations of the nearest city market.

As a matter of fact, only a very small percentage of the annual hay crop is sold on the market while it contains an abnormally large amount of water, for during the time it is going through the "sweat," in the barn or stack, which usually continues from 3 to 6 weeks, hay is not marketable and is not in condition even to be baled. Hence there is no logical reason for assuming that the water lost during this period of the curing process causes a loss to the producer, since the hay is not a marketable product until shrinkage is over.

Neither is there any valid reason for assuming that the price of hay at haymaking time, when both old and new hay are scarce, should set the price of hay for the remainder of the year. The price of new hay during July and August is much higher in several of the leading markets than during the winter months when shrinkage has ceased. The high price of new hay is due, in part, to the comparatively small amount baled, and to the fact that during July and August farmers are too busy with such crops as hay, corn, and small grain to haul hay to market. In other words, new hay often sells for more than it is really worth, if we consider the high percentage of water it sometimes contains and the price of thoroughly cured hay during the winter months. The 20-year average monthly price ("high") of timothy in four leading markets is shown graphically in figure 1.

The amount of newly made hay sold loose from the field during the hay-making period is comparatively small, and the local price has no effect on the price of thoroughly cured market hay later on. If the price of new hay happens to be lower when hauled from the field than the price of thoroughly cured hay later, it is not necessarily because its large water content is taken into consideration, but more likely because the cost of baling is eliminated, as is also the cost of hauling and storing away or stacking, if the buyer does the hauling.

There is also another very serious and practical objection to the recommendation that the producer protect himself against loss of water by price fixing. Let us assume, for the moment, that the producer is able to fix prices on hay so that he will receive the same rate, based on the price of hay at harvest time, for a ton of dry matter during the entire year. Here the impracticability of this

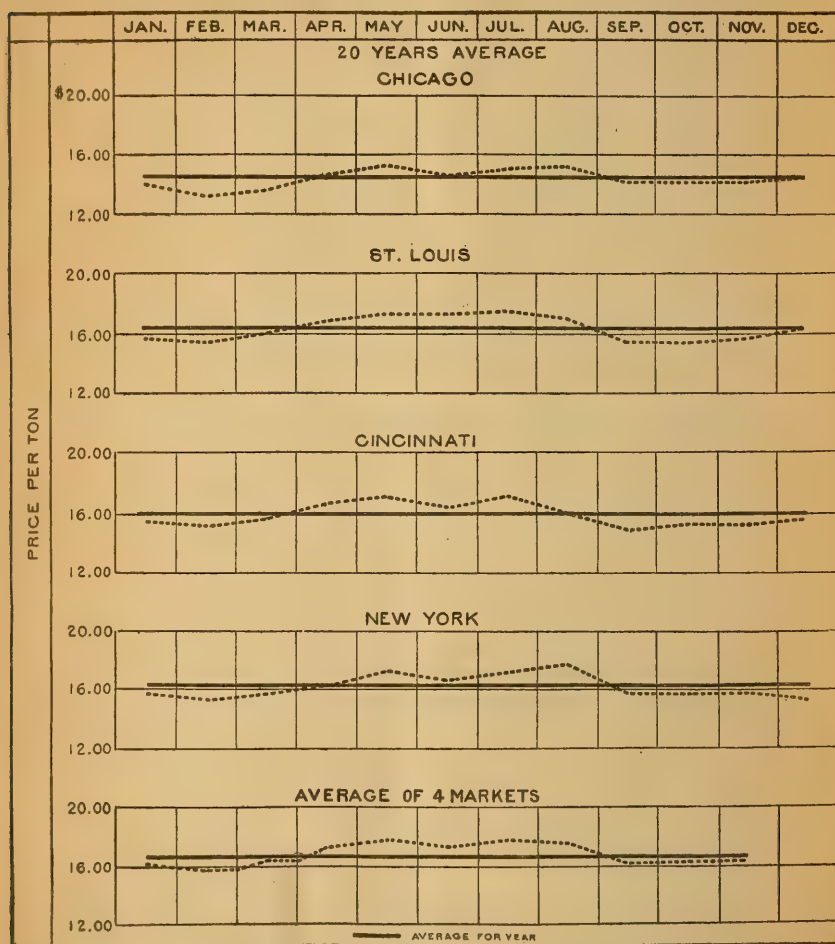


FIG. 1.—Average "high" price per ton of timothy hay, by months, for 20 years, 1896-1915, for four leading hay markets. (Data compiled from Yearbooks of the U. S. Department of Agriculture.)

scheme becomes evident. How can the producer determine the water content of his hay so that he can fix the price before it is sold? He can not very well reach all parts of the mow or stack to get the sufficient number of average samples to ascertain the actual water content by a chemical analysis. Samples can easily be taken while the hay is being baled, but the greater percentage of hay is sold or

the price per ton is agreed on before it is baled. For these and other reasons it seems evident that if the hay grower takes advantage of what he considers a good offer for his hay he may safely forget about any so-called loss because of shrinkage.

This view was also held by Failyer³¹ 30 years ago. Writing in 1888, which was about the time that many of the earlier experiments were being made to determine the rate of shrinkage in hay, he said, in discussing the results of a number of shrinkage experiments, made with several kinds of hay: "The conclusion to be drawn from these results is that if the hay is not obviously green and illy cured, no great shrinkage need be feared."

Failyer did not favor advancing the price of hay as it cured out in the stack or barn to make up for the loss of water. Instead of using the price of hay at harvest time as a basis for computing the value of thoroughly cured hay in winter, he advocated the reverse. He figured the value of newly made hay from that of hay after shrinkage had taken place. In discussing an experiment in which there was shown a loss of 10 per cent of water, and which he regards as an exceptional case, he says:

Even in these excepted cases the shrinkage is much less than many suppose. * * * This [referring to a 10 per cent loss] means that a ton of the hay as hauled in [field cured] would weigh only 1,800 pounds in the winter, and that if a ton of this hay weighed in midwinter is worth four dollars, the ton weighed at the time the sample was buried [when put into the barn] would have been worth three dollars and sixty cents. This would be worth considering; but in most cases the loss is much less than this.

LOSS TO SHIPPER AND COMMISSION MERCHANT.

Shrinkage sometimes causes a loss of money to those who make a business of dealing in market hay. Such loss may be entailed when hay is held in storage, in the bale, waiting for a favorable market. The amount of shrinkage in hay that has passed through the sweat is not large, yet if large quantities of hay are held in storage the total shrinkage will "run into dollars" very quickly.

Loss of this kind is most likely to be sustained in storing hay that has been baled from the windrow or cock and bought immediately. When those who handle this class of hay dispose of it quickly they suffer no serious loss of money through shrinkage. In other words, as long as the hay is kept moving from shipper to commission man, and from him to retailer or consumer, no one person who handles the hay will lose very much on account of shrinkage, except possibly the consumer. If the hay is held in storage the loss may sometimes be made up by disposing of it on a good market. Those who make a business of speculating in hay count on the price advancing sufficiently to cover the loss from shrinkage and allow them a profit besides.

³¹ Kansas Agricultural Experiment Station. First Annual Report, 1888, pp. 117-121.

The dealer may lose money on account of shrinkage when he buys a certain undoubted amount of excess water in the hay at the price of market hay. Therefore he is wholly justified in assuming that when this loss is caused by shrinkage it is a positive money loss. In order to make up for such loss he advances the selling price when it is within his power to do so.

WHAT IS HAY?

The misunderstandings regarding shrinkage, especially those bearing upon economic phases, would never be so widespread as they are to-day if there were a clear and definite understanding as to just what is hay, and if there were standard terms used to designate the kind or condition of hay at any stage of curing.

It may seem, at first thought, that it is a comparatively easy matter to describe or define hay so that all of those engaged in the production or utilization of this crop may have a common, definite understanding concerning it, a product with which almost everyone is more or less familiar. It is only when one undertakes to define the term that he begins to appreciate the difficulties that make practically impossible the framing of a single definition that will embrace all of the different kinds of hay and that will be acceptable to all classes of people engaged in the hay industry.

These difficulties have nothing to do with the question of grades or quality of hay as they are known on the market, because the question of grade concerns only a definite and well-understood kind of hay. The unqualified term "hay," however, may mean any one of a great number of things, from grass that has been just cut to hay that contains less than the normal water content. In view of this fact it becomes apparent that to be able to define precisely it will be necessary to have not merely one, but several definitions, each of which should describe accurately a particular kind of hay.

INDISCRIMINATE USE OF TERMS.

No one class of men concerned with the hay industry may be said to be responsible for the present conflicting ideas as to just what constitutes hay. Hay, in the farm management or labor sense, may be something quite different from hay as viewed from the standpoint of the city commission man or the consumer. For example, it is quite common, indeed almost universal, for the farmer to speak of "mowing hay," "tedding hay," or "cocking hay," when as a matter of fact the material thus spoken of is not in reality hay at all. Strictly speaking, we mow grass, and use the tedder on fresh or partly cured forage that is being made into hay.

The many terms commonly used to describe hay that is ready to be put into the stack, barn, or bale are given in Table III.

TABLE III.—*Terms variously used by growers to describe the condition of hay when put into the barn, stack, or bale.*

[Actual condition of the hay.]

	Fairly well cured: Evenly cured, but water content too high. High degree of fermentation indicated, considerable shrinkage, destruction of dry matter, and possibly discoloration.	Well cured: Entire plant cured out evenly and sufficiently. Will have a normal shrinkage and make "choice" hay.	Overcured: Stems brittle. Leaves dead, dry, and sunburnt. Will be little or no shrinkage; possibly a gain in water in storage. Will make medium to poor quality of hay.
Undercured: Stems full of sap but leaves dead and dry. Spontaneous combustion and heavy shrinkage indicated.			
Green.....	Green.....		
Slightly green.....	Slightly green.....		
Tough.....	Tough.....	Tough.....	
Damp.....	Damp.....	Damp.....	
	Fairly dry.....	Fairly dry.....	
	Fairly well cured.....	Fairly well cured.....	
		Well cured.....	
	Dry.....	Dry.....	Dry.....
	Cured.....	Cured.....	Cured.....
	In good condition.....	In good condition.....	In good condition.....
	Successfully cured.....	Successfully cured.....	Successfully cured.....
Fit.....	Fit.....	Fit.....	Fit.....
	Ready to haul.....	Ready to haul.....	Ready to haul.....
		In good shape.....	In good shape.....
		Ready to bale.....	Ready to bale.....
Swath-cured.....	Swath-cured.....	Swath-cured.....	Swath-cured.....
Windrow-cured.....	Windrow-cured.....	Windrow-cured.....	Windrow-cured.....
Cured in cock.....	Cured in cock.....	Cured in cock.....	Cured in cock.....
Cured in bunch.....	Cured in bunch.....	Cured in bunch.....	Cured in bunch.....
Field-cured.....	Field-cured.....	Field-cured.....	Field-cured.....

Many of these terms are used interchangeably, and often it will be found that a term which means one thing in one locality will mean something else in another. Thus "tough" hay may be either hay that is undercured or hay that has been thoroughly cured out but has become dampened by dew or rain. The terms "successfully cured," "ready to haul," "swath-cured," "bunch-cured" or "windrow-cured," are all more or less confusing and are interpreted differently by individual haymakers. To one, "dry" hay in the field is hay that is ready to haul to the barn or stack but will be subject to a normal amount of shrinkage. To another, "dry" hay is hay that has been overcured, while those who bale from the field think of "dry" hay as hay ready for baling without serious heating or loss of moisture in the bale.

It is only natural that hay producers should occasionally describe conditions of field-cured hay in local terms that are misleading to farmers in other parts of the country. There is less excuse, however, for the spreading of the same confusion by official scientific publications.

A review of the literature on shrinkage experiments shows that sometimes investigators themselves do not understand clearly what constitutes hay, or at least they have not used terms that accurately describe the material with which they were experimenting.

In experiment 5, page 5, "well-cured" hay lost 22.6 per cent by shrinkage, while in experiment 11, page 5, hay that was only "fairly well cured" lost only one-half as much, or 11.2 per cent.

In experiment 18, page 6, hay that was "unusually dry" lost 3.6 per cent by shrinkage, while the hay in experiment 11 which was "very dry" lost 11.2 per cent by shrinkage, or more than three times as much water as the hay that was "unusually dry." These two terms should be practically synonymous, yet the results with two lots of hay varied greatly.

It has been shown that the general term "hay" is universally used to describe material that varies in degree of curing from that of "hay" that is nothing more than green forage to "hay" that is so dry that it contains but 3 per cent of water. Since it is not to be expected that such general and long-established usage will be changed, it becomes necessary, for convenience, so to qualify the general term as to make terms that specifically and accurately apply to the several different stages through which hay passes before it becomes what in the strict sense would be classed as hay, that is to say, the kind that is recognized as hay on the market.

In compiling the following suggested definitions of different kinds of hay, as determined by stage of curing, the experience and terminology of shippers, receivers, and farmers in the several hay-growing sections of the country have been drawn upon. No attempt has been made, of course, to define the various grades and mixtures of market hay.

The definitions here suggested deal only with the several stages in the process of curing.

DEFINITIONS OF HAY.

Market hay.—Hay that is thoroughly cured and can be baled immediately and marketed if it is so desired is market hay. (The term "market hay" has been used in this sense in this bulletin.) The trade rules for the better grades of hay require, in part, that the hay shall be *properly cured, sound*, and of a good or otherwise specified color. In order to meet these requirements hay must go through the sweating or final stage of the curing process. Properly cured, sound hay which has gone through the sweat can contain only the normal percentage of water, except during long periods of extremely wet or dry weather. Even then the water content will not vary more than a few per cent either way from normal. The question of shrinkage or loss of water in market hay need not concern the hay producer, since there is just as great a chance of a gain above the normal content as there is of loss in many sections of the United States.

New hay.—New hay is a term used on the city market to distinguish the current crop from last year's crop. It is most frequently applied to hay that has been baled from the field and shipped to market. It is not used after the "old" hay crop has been disposed of.

Old hay.—Old hay is a market term used, after hay has been harvested, to describe last year's crop.

Hot hay.—Hot hay is a term frequently applied to hay, especially alfalfa hay that reaches the market while undergoing sweating. Hot hay is in the final stage of curing. The heating may sometimes be caused by tight packing in a car with a metal roof which becomes hot and starts the heating. If new hay is a long time in transit it often heats, whereas if it reaches the market quickly and is unloaded and properly piled in a warehouse, heating may sometimes be avoided.

Dry hay.—Dry hay is a market term used, especially in the West, when hay has become so dry that it shatters easily when handled. This kind of hay is thought by some feeders to lack palatability. The term "dry" is used locally to denote the condition of hay when ready to be put into the barn or stack, and also to describe hay after shrinkage has ceased.

Green hay.—A term proposed for use on the farm to describe all hay that has been field-cured but is not sufficiently cured to be baled and marketed is green hay. Such a term would correspond, in a way, to the term "green" as applied to unseasoned lumber to distinguish it from air-dried or kiln-dried lumber, and would have no special reference to the color of the hay. If this or some other more appropriate term were customarily used in speaking of hay in the barn or stack while it is in the sweat or heating period, during which time the larger part of the water lost by shrinkage occurs, it would tend to correct the hay growers' impression that shrinkage causes an actual money loss. After "green" hay has passed through the sweat it becomes "new" (market) hay.

Barn or stack cured hay.—The farm terms barn-cured or stack-cured hay are sometimes used in speaking of hay that has passed through the final (sweating) stage of curing and is ready to be baled and shipped. Very little, if any, shrinkage is likely to occur in hay that has been thoroughly cured in the barn or stack.

Field-cured hay.—Field-cured hay is a very indefinite term embracing all of the terms given in the list on page 29. It is used to denote the degree of curing in the field. When partially-cured hay is put into the stack, barn, or bale it is said to be "field-cured."

The degree of curing of this kind of hay is not always the same, since it depends on how the hay is to be utilized. If hay is to be put into the barn or stack, then field-cured hay, in sections where the weather is subject to sudden changes, should be cured just enough so that it will go through the sweat without developing temperatures that will injure the hay. This is done to avoid, as far as possible, any danger of loss by sun and rain which may occur if the hay is left exposed too long in the field. A shrinkage of 10 or 15 per cent in field-cured hay is to be expected as a part of the natural curing process.

If the hay is to be baled in the field, from the windrow or cock, it must be cured out more than when it is to be put into the barn or stack. The curing should be carried as far as possible without making the hay so brittle that it will break or shatter easily when being baled. The loss of water by shrinkage will be considerably less in hay properly field-cured than in hay properly field-cured to be put in barn or stack.

First-cutting hay, etc.—The terms “first-cutting hay,” “second-cutting hay,” etc., are used to distinguish different crops of hay, such as alfalfa and clover that are cut more than once a year. It has become necessary to use these terms in the market, especially for alfalfa, because a consumer may, for various reasons which are not always very clear or well-based, prefer a certain cutting for feeding a certain class of stock.

SUMMARY.

(1) The question of shrinkage is one that has always been of interest to those engaged in the production and utilization of hay. The producer wants to know how much hay shrinks because he believes that it results in a direct money loss when he grows hay for the market. The shipper and dealer want to know how much hay shrinks, so that they can make allowance for this factor and thereby avoid disputes and losses.

(2) The percentage of shrinkage in hay is influenced by the following factors: (1) water content when cut, (2) maximum water content when stored, (3) normal water content when cured, (4) minimum water content, (5) atmospheric humidity, and (6) effect of time.

(3) Many experiments have been conducted, during the last 30 years, to determine the rate of shrinkage in hay in the barn and stack. The loss in weight was found to range from 0.29 per cent to 42.2 per cent and the gain in weight ranged from 0.4 per cent to 10.7 per cent, making a total variation of about 53 per cent.

(4) All efforts by investigators to determine the average rate of shrinkage, in order to formulate a definite rule to be used at harvest time to calculate the percentage of “dry” or marketable hay, have failed. The reason an unvarying shrinkage rule can never be used for a large producing territory is because of the effect of such factors as variation in the time of cutting, methods of curing, and the weather, which will always cause a wide difference in the percentage of shrinkage in hay on individual farms within a given territory.

(5) The experiments show that there is no correlation between the lapse of time and the percentage of loss by shrinkage. In other words, the amount of loss that may occur during 3 months has no mathematical relation to the amount occurring during 6 months, 9 months, or other period.

(6) The widespread publication of experimental data showing comparatively large losses by shrinkage, during several months, has been misleading, especially to producers, because the investigators failed to point out *that the greater part of the loss occurs before the hay is in proper condition to be baled or marketed* and that the loss, which is practically of water only, is simply a part of the natural curing process, and, therefore, should have no commercial value.

(7) If hay is marketed in the proper condition, shrinkage does not affect the profits of the producer until after the final curing stage, known as fermenting or sweat stage, has been finished in the stack or barn and the water content has become normal. The shrinkage that actually affects the producer's profits is due to a relatively small loss in weight caused by continued dry weather which lowers the normal water content of marketable hay. This loss is liable to be offset by the increase in water above normal, which takes place during the damp weather when hay absorbs water from the air.

(8) Shrinkage causes an actual loss to the shipper or dealer when he buys and stores hay containing more than the normal water content for well-cured barn or stack-cured hay (*a*) when the hay has been baled from the windrow or cock and is bought before it has gone entirely through the "sweat," or (*b*) when a large mow or stack is baled and sold immediately after having gone through the "sweat." In the first instance practically every bale will shrink more or less, while in the second instance only the hay from the interior of the pile will lose in weight.

(9) There is practically no loss of dry or nutrient matter during the shrinkage of hay while in the barn or stack, provided the hay has been properly cured before it is hauled from the field. Undercured hay, containing an excessive amount of water, is liable to become so hot in the barn or stack that it will become discolored, charred, or, in extreme cases, entirely burned up by spontaneous combustion.

(10) Under certain conditions the producer can determine how much shrinkage to expect in hay produced on his farm. These conditions necessitate (*a*) an adequate, full sized, experienced haymaking crew; (*b*) the use of a definite, efficient, and practically unchangeable method of operation and curing; and (*c*) comparative freedom from interference by unfavorable weather. Under these conditions the average shrinkage can be determined by weighing a given quantity or by a water analysis. The percentage of shrinkage found will be applicable until the conditions are changed.

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Farm Economics

H. C. TAYLOR, Chief

In Cooperation with the Iowa Agricultural Experiment Station
C. F. CURTISS, Director



Washington, D. C.

PROFESSIONAL PAPER

August 23, 1920

FARM LAND VALUES IN IOWA.

By L. C. GRAY, *Agricultural Economist in Charge of Land Economics, Office of Farm Management, and Farm Economics*, and O. G. LLOYD, *Assistant Chief in Farm Management, Iowa Agricultural Experiment Station*.

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PURPOSE, SCOPE, AND METHOD OF INVESTIGATION.

The investigation upon which this bulletin is based was undertaken to determine the extent of increase in prices of Iowa farm lands, with special reference to the year 1919, the causes of the unusual activity in the buying and selling of lands in that year, and the probable effects of this activity upon the farming industry in the State of Iowa.

It was considered of special importance to ascertain what changes have occurred in the relationship between farm land values, farm earnings, and the shares received by landlords and by tenants, and to determine the probable effect of these changes on the opportunity of farmers to acquire the land they cultivate. It was also believed that the investigation would be of some value as a study of the phenomena of land speculation, an important topic in the general subject of land economics.

Unusual activity in land transfers and rapid increases in the prices of farm land have occurred over wide areas throughout the United States during the past year. If the resources for investigation had

To obtain comparative data concerning farm earnings for the year 1918 a farm management survey was made covering about 400 farms in the same areas. A large number of these farms were the same for which data had been obtained in previous surveys.¹

TREND OF LAND VALUES IN THE COUNTRY AS A WHOLE.

Before beginning the study of farm land values in Iowa it is desirable to determine the extent of the area in the United States characterized by a marked advance in farm land values such as has occurred in that State.

In Table I, which comprises unpublished data supplied by the Bureau of Crop Estimates, are shown the estimated average values per acre of farm land and improvements for all the States, together with the estimated increase per acre and per cent of increase from March 1, 1919, to March 1 1920

TABLE I.—Average value of farm land and improvements, by States, 1915, 1919, 1920, and increase per acre and per cent of increase, 1919 to 1920. (Estimates obtained by the Bureau of Crop Estimates.)

State.	Average value per acre.			Increase 1919 to 1920.		State.	Average value per acre.			Increase 1919 to 1920.	
	1915	1919	1920	Per acre.	Per cent.		1915	1919	1920	Per acre.	Per cent.
Maine.....	\$36.00	\$47.00	\$52.00	\$5.00	10.6	N. Dakota.....	\$34.00	\$43.00	\$50.00	\$7.00	16.2
N. Hampshire.	37.00	45.00	52.00	7.00	15.5	S. Dakota.....	58.00	80.00	110.00	30.00	37.5
Vermont.....	39.00	47.00	53.00	6.00	12.7	Nebraska.....	71.00	105.00	135.00	30.00	28.5
Massachusetts.	72.00	80.00	100.00	20.00	25.0	Kansas.....	53.00	69.00	80.00	11.00	15.9
Rhode Island.	95.00	90.00	95.00	5.00	5.5	Kentucky.....	38.00	81.00	85.00	4.00	4.9
Connecticut.	63.00	67.00	85.00	18.00	26.8	Tennessee.....	38.00	65.00	77.00	12.00	18.4
New York.....	65.00	75.00	88.00	13.00	17.3	Alabama.....	20.00	29.00	38.00	9.00	31.0
New Jersey.....	90.00	113.00	125.00	12.00	10.6	Mississippi.....	20.00	32.00	45.00	13.00	40.6
Pennsylvania.	64.00	79.00	92.00	13.00	16.4	Louisiana.....	30.00	43.00	65.00	22.00	51.1
Delaware.....	63.00	78.00	94.00	16.00	20.5	Texas.....	40.00	55.00	69.00	14.00	25.4
Maryland.....	56.00	69.00	91.00	22.00	31.8	Oklahoma.....	29.00	43.50	55.00	11.50	26.4
Virginia.....	34.00	60.00	68.00	8.00	13.3	Arkansas.....	23.00	42.00	55.00	13.00	30.9
W. Virginia.....	34.00	51.00	58.00	7.00	13.7	Montana.....	35.00	39.00	42.00	3.00	7.6
N. Carolina.....	33.00	47.00	75.00	28.00	59.5	Wyoming.....	35.00	50.00	60.00	10.00	20.0
S. Carolina.....	30.00	53.00	75.00	22.00	41.5	Colorado.....	55.00	66.00	75.00	9.00	13.6
Georgia.....	24.00	45.20	57.00	11.80	26.1	New Mexico.....	52.00	62.00	62.00	0.00	0
Florida.....	40.00	60.00	72.00	12.00	20.0	Arizona.....	107.00	130.00	185.00	55.00	42.3
Ohio.....	86.00	109.00	130.00	21.00	19.2	Utah.....	85.00	130.00	150.00	20.00	15.3
Indiana.....	90.00	120.00	145.00	25.00	20.8	Nevada.....	85.00	90.00	90.00	0.00	0
Illinois.....	126.00	164.00	204.00	40.00	24.3	Idaho.....	66.00	97.00	125.00	28.00	28.8
Michigan.....	61.00	80.00	87.00	7.00	8.7	Washington.....	99.00	115.00	150.00	35.00	30.4
Wisconsin.....	80.00	109.00	130.00	21.00	19.2	Oregon.....	75.00	95.00	120.00	25.00	26.3
Minnesota.....	65.00	94.00	124.00	30.00	31.9	California.....	175.00	218.00	190.00	28.00	-----
Iowa.....	134.00	192.00	255.00	63.00	32.8						
Missouri.....	58.00	82.00	104.00	22.00	26.8	United States.	59.91	81.89	99.24	17.35	21.1

¹ Acknowledgment is due the farmers and other business men who made this study possible and to the members of the staff of Iowa State College and of the Office of Farm Management, U. S. Department of Agriculture, who aided in the gathering and tabulation of the data used.

Survey data for 1913 and 1915 were collected by H. B. Munger, J. Whitson, Wm. Brand, Russell Engberg, Fred C. Fenton, R. J. Leth, E. H. Lott, W. T. Maaksted, M. B. Posten, Geo. X. Reed, Harold W. Reid, Louis Sawyer, Allan M. Smith, and L. B. Snyder, of the Farm Management Department, Ames, Iowa. Prof. H. B. Munger supervised the collection and tabulation of the results.

The data for 1918 and 1919 were collected by Earl D. Strait, C. O. Brannen, II. H. Clark, J. S. Donald, R. D. Jennings, Bruce McKinley, J. C. Rundles, C. F. Sarle, F. H. Shelly, and C. C. Taylor, of the Office of Farm Management, United States Department of Agriculture. Messrs. Howard A. Turner and J. C. Rundles supervised the tabulation of the results.

It is clear that the advance of land values in Iowa is only part of a general rapid upward trend of land values, the average increase for all the States amounting to \$17.35 per acre, or 21.1 per cent. In only one State, California, have land values declined during the year. Even in New England the value of farm lands increased over \$10 an acre, or 16.2 per cent, the increase being most marked in Massachusetts and Connecticut. In the other Atlantic States the increase in value per acre was most notable in the Carolinas, reflecting the influence of high prices for cotton, "bright" tobacco, and peanuts. The increases for Virginia and West Virginia were comparatively small. The increases in values in the other Atlantic States are between the two extremes. The largest average increase per acre in the United States, but not the largest percentage of increase, occurred in Iowa, followed by Arizona and Illinois. Throughout the States lying largely in the Corn Belt there were increases per acre ranging from \$21 in Ohio to \$63 in Iowa, with the exception of Kansas, where the increase was only \$11.

In States characterized by a fair degree of uniformity in agricultural resources, as in many of the States in the Corn Belt, averages for the State as a whole are frequently not indicative of the movement of values in certain sections. Thus, the increase for Kentucky averages only \$4 an acre, yet in the Blue Grass Region there has been a very marked increase in farm land values and extraordinary activity in the buying and selling of land. There has been a considerable increase in the value of farm lands in Michigan, but the average for the State is low because of the influence of the large areas of cut-over lands in parts of the State. In the South the percentages of increase are large, although they do not represent large increases per acre.

INCREASE IN THE AVERAGE VALUE PER ACRE OF IOWA FARM LAND SINCE 1850.

TABLE II.—*Increase in the average value of improved farm land in Iowa from 1850 to March 1, 1920.*

Year.	Value per acre.	Increase per acre.	Year.	Value per acre.	Increase per acre.
1850.....	\$6.09		1915.....	\$134.00	\$38.00
1860.....	11.91	\$5.82	1916.....	153.00	19.00
1870.....	20.21	8.30	1917.....	156.00	3.00
1880.....	22.92	2.71	1918.....	174.00	18.00
1890.....	28.13	5.21	1919.....	192.00	18.00
1900.....	43.31	15.18	1920.....	255.00	63.00
1910.....	96.00	52.69			

The statistics for the years 1850 to 1910, inclusive, are from the Federal census. The statistics for 1915 to 1920, inclusive, are from unpublished data furnished by the Bureau of Crop Estimates, United States Department of Agriculture.

During the last decade the percentage increase, as well as the dollars per acre increase, was larger than that for any other decade in the history of the State. During the past year the increase in dollars per acre was greater than during the 50-year period from 1850 to 1900. From 1915 to 1920, the smallest increase in the price of land was in the year before the United States entered the World War, and the largest increase was the year following the signing of the armistice.

AVERAGE PRICES FOR 60 COUNTIES, 1918 TO 1919, WITH SPECIAL REFERENCE TO THE PERIOD OF THE "BOOM."¹

TABLE III.—Average price of improved farm land per acre and percentages of increase in 60 Iowa counties, 1918 to 1919.

	Number of farms.	Average price per acre.	Increase over estimate of March, 1918.	
			Per acre.	Per cent.
Estimated average value per acre March, 1918, of 1370 farms subsequently sold in 1919.....	1,370	\$194		
Sales of farms, January to March inclusive, 1919.....	127	237	\$43	22.2
Sales of farms:				
April, 1919.....	120	240	46	23.7
May, 1919.....	244	238	44	22.7
June, 1919.....	382	247	53	27.3
July, 1919.....	367	255	61	31.5
August 1919.....	158	259	65	33.5
September, 1919.....	16	276	82	42.3
All sales:				
January to September, 1919.....	1,414	248	54	27.8
June to September, 1919.....	923	253	59	30.4

In order to determine the extent of change in land values in the region studied it was considered necessary to have an estimate of the value of farm lands on March 1, 1918, a date about one year before the general public became aware of the increased activity in sales of land and the marked increase of land values.

The result of 1,370 estimates of the values of individual farms in the 60 counties indicates an average value of \$194 per acre on March 1, 1918. This figure is \$20 higher than the estimate by the Bureau of Crop Estimates for the State as a whole. Previous statistics for 1915 indicated that the average value of farm land in the 60 counties studied is about \$11 per acre higher than the average for the entire State. The remaining difference of \$9 between the two estimates is attributable to the fact that the farms which changed hands most frequently in the region studied during the period of the recent activity were above the general average in quality for the region as a whole.²

¹ Throughout this bulletin the word "boom" is employed as a convenient expression to designate a period of unusual activity in the buying and selling of land accompanied by a considerable amount of speculation.

² A number of checks have been available, as follows: (a) The unpublished figures of the Bureau of Crop Estimates, quoted above; (b) results of investigations in 55 counties of the executive board of the State of Iowa for the period from January 1, 1918, to May 1, 1919, based on sales; (c) estimates prepared by Mr. T. A. Polleys, tax commissioner of the Chicago & Northwestern Railway, based on executors', administrators', and referees' sales, and inheritance tax appraisals in 19 counties; (d) results of a questionnaire sent by Senator H. S. Van Alstine to bankers in all the counties of the State; (e) estimates by 222 bankers and real estate men obtained by the field agents of the Office of Farm Management; (f) estimates on 238 farms for which data on net rentals were obtained by field investigators of the Office of Farm Management; and (g) estimates obtained in farm management surveys of over 400 farms in selected districts.

From a number of sources of information it has also been possible to check the accuracy of the increase shown by the table to have occurred from March 1, 1918, to August, 1919. According to this information it appears that from March, 1918, to March, 1919, the time the increased activity in land sales began to be manifested, there was an increase of not less than \$15 per acre and possibly as much as \$20.

Table III shows an average increase from the first of March, 1918, to August, 1919, of \$65 per acre. This may be compared with the increase of \$81 per acre from March, 1918, to March, 1920, according to the statistics of the Bureau of Crop Estimates. The latter figure reflects the full extent of the "boom," showing that there was an increase between August, 1919, and the cessation of unusual activity in sales of farms.

Assuming that the increase from March, 1918, to the beginning of the "boom" was \$15 per acre, there remains an average increase of \$50 to be attributed to the advance during the "boom" up to about the middle of August. There was probably a further increase before the cessation of activity in buying and selling land about the middle of September amounting to about \$16 an acre. Consequently it appears that an average increase of \$66 an acre may be attributed to the farm land "boom" of 1919.

It will be noted that the increase shown by the data on sales in Table III for the period of the "boom" for March to August inclusive, is only \$33 as compared with a probable average increase, as stated above, of approximately \$50. Two facts probably account for this. In the first place, the "boom" was really a popular awakening to an increase in values that had been going on steadily in the pre-"boom" period. When the awakening came there was a sudden jump in values manifested in the early months of the year. A second explanation is the tendency to sell the best grade of farms first. A supplementary investigation was made for the purpose of verifying this conclusion. A typical district was visited and additional sales data were obtained for 194 farms. These farms were classified into "A" grade and "B" grade farms, the first group having an average price of \$340 an acre and the second group, \$261. It was found that 30 per cent of the "A" grade farms were sold between January 1 and April 1, 1919, while only 18 per cent of the "B" grade farms were sold during the same period.

PROBABLE INCREASE IN VALUE OF LAND IN ENTIRE STATE, 1915 TO 1920.

On the basis of the figures given in Table II there has been an increase in the average value of Iowa farm land that is little short of astounding. The average value of Iowa farm land increased \$121 an acre from 1915 to 1920. This represents a total increase of \$3,987,-

077,776 for the entire State on the basis of the farm acreage of 1915. Of this enormous increase, \$63 an acre occurred from March, 1919, to March, 1920, the period of the boom, an increase for the entire State of \$2,075,916,528.

It is true that some of these increases represented additions of buildings, fences, and other similar farm improvements. It seems improbable, however, that a very large proportion of the increase is represented by these factors. Indeed, the value of improvements according to the Census of 1915 was only \$479,903,698, as compared with \$455,405,671, the value of buildings according to the Census of 1910, an increase of only 5.3 per cent.¹ However, there is one kind of farm improvement, drainage, not included in the above figures, a kind of improvement which probably is responsible for a considerable part of the increase in the value of farm lands. The activity in drainage of farm lands has been especially great in north central Iowa.

So striking an increase in the values of farm lands in a single State could not fail to have profound economic significance. While it is too early to determine all the economic consequences, it is time careful attention were given to the phenomena, and that serious consideration were devoted to the problem of determining what bearing this enormous increase may have upon the welfare and prosperity of the farmer, the progress of the farming industry, and the future land policies of the United States.

RANGE OF PRICES PAID FOR FARM LAND.

While the average price of land, as shown above, was \$248 for sales from January to September and \$259 for the month of August, it is important to consider the range of prices that result in the above averages. In Table IV is shown the range of prices paid in 1,448 sales of farms from January to September, 1919.

TABLE IV.—*Sales of farm land, classified according to price per acre.*

	Number of sales.		Number of sales.
Under \$100 per acre.....	10	\$350 and under \$400.....	83
\$100 and under \$150.....	91	\$400 and under \$450.....	38
\$150 and under \$200.....	301	\$450 and under \$500.....	16
\$200 and under \$250.....	372	\$500 and over.....	10
\$250 and under \$300.....	302		
\$300 and under \$350.....	225	Total.....	1,448

It will be noted that more than 80 per cent of the sales range from \$150 to \$350 per acre. Less than 5 per cent were \$400 an acre or more. Only a few sales were found at \$500 an acre or more. Among

¹ The figure in 1910 is for buildings, while in 1915 it is for "improvements." It is probable they represent substantially identical units of comparison.

these there were several sales at \$600 or more. The writers have found references to a number of other cases of sales at \$600 or more in a large number of clippings from Iowa newspapers. In one case the rate of sale was more than \$900 per acre. This, however, involved only 10 acres of land and probably represented residential value. It is also true that a considerable number of other sales at \$600 or more were small tracts, probably used as truck farms or for some other intensive purpose. The importance of the comparatively few sales at \$400 or more was so exaggerated by newspaper publicity that the general public were led to believe \$400 to be the going value of Iowa farm land as a whole.

EXTENT OF ACTIVITY IN BUYING AND SELLING FARMS, 1919.

PERIOD OF THE "BOOM."

Taking the State of Iowa as a whole, the unusual activity in land sales covers the period from the early spring of 1919 until the middle of the month of September. There are some indications that increased activity in land transfers occurred in certain counties in the fall of 1918, especially in Sioux, Plymouth, Cass, and Sac Counties. For this reason investigators were frequently told that the "boom" began in northwestern Iowa and spread from that region as a center. It seems clear, however, that while this tendency for the activity to spread from one county to another was more or less manifest and was intensified in every county by the stories of activity and of rapidly increasing values of other parts of the State, as well as by the movement from county to county of real estate agents, speculators, and buyers seeking to replace lands already sold, the entire movement was more or less spontaneous throughout the State. It was unquestionably due largely to general conditions everywhere favorable to such a tendency. Broadly speaking, the activity probably began a little earlier in some of the counties in the northwestern part of the State and a little later in some of the counties of the northeastern part of the State than in the majority of counties.

PROPORTION OF FARMS SOLD.

From the degree of excitement which prevailed during the spring and summer of 1919, one might have formed the conclusion that nearly all the farms of the State of Iowa were changing hands. In order to determine what proportion of the farms of the State were actually being sold, inquiries were made of real estate men, bankers, and other well-informed persons as to what proportion of the farms of their communities had changed hands during the "boom." The average of 93 estimates from 34 counties is 8.9 per cent¹, or 6,250

¹ A recent statement issued by a large Iowa trust company gives 19,600 as the number of farms sold during the "boom." This is approximately 10 per cent of the farms of the State, but the estimate covers a longer period than that given above.

farms out of a total of 70,053 as reported by the 1915 Census. There seem to be no conclusive data as to what percentage of sales would have occurred under normal conditions. However, some indication may be furnished by figures contained in a survey of Orange Township, Blackhawk County, Iowa, by Mr. George H. Von Tungeln, of the Iowa State College. According to this study, 6,936.66 acres in 48 tracts changed hands during the five-year period from August, 1910, to August, 1915. This represented about one-third of the number of farms with residences and a little less than one-third of the farm acreage of the township, or an average of about 6 per cent a year as compared with the estimate of 8.2 per cent for the period of the "boom." However, the activity in land transfers in the region in which Orange Township is located was greater than normal during the period from 1910 to 1915, inclusive.

EXTENT OF RESELLING DURING THE "BOOM."

It is probable that one travelling through the State of Iowa during the period of the "boom" would have gotten the impression that a large proportion of the farms sold changed hands more than once during the period. In fact, one heard of these cases frequently. The newspapers continually published instances of farms which sold from three to six times. The data concerning farm sales, however, do not indicate that the reselling of farms was practiced as extensively as might be indicated by casual observation. Of 1,024 farms sold between January 1, 1919, and the end of August, 1919, 693, or 67.7 per cent, were sold but once; 261 farms, or 25.5 per cent, were sold twice; 48 farms, or 4.7 per cent, were sold three times; and 22 farms, or 2.1 per cent, were sold four times or more. However, a number of instances came to the writers' attention of farms sold five or six times during the period.

Although the instances of reselling were less numerous than one might have believed from reading the newspapers during the "boom," the process was much more extensive than in normal periods. In short, this reselling was a characteristic land "boom" phenomenon.

PERSONS ENGAGED IN BUYING AND SELLING.

BUYERS AND SELLERS CLASSIFIED BY OCCUPATION.

In order to determine the real character and significance of the recent activity in land sales it is important to know what classes of persons were most active in the buying and the selling of farms. To this end the residence and occupation of each buyer and the occupation of each seller were ascertained. Table V presents a classification of buyers and sellers according to their occupations.

TABLE V.—*Purchasers and sellers of farms, classified by occupations.*^a

Occupation.	Buyers.		Sellers.	
	Number.	Percent. ^b	Number.	Percent. ^b
Farmers.....	662	65.3	513	56.3
Retired farmers living in country.....	18	1.8	138	15.2
Retired farmers living in town.....	47	4.6		
Real estate men.....	70	6.9	104	11.5
Bankers.....	61	6.0	30	3.3
Merchants.....	42	4.1	29	3.2
Commission men, produce dealers, auctioneers, and traveling salesmen.....	22	2.1	24	2.7
Government employees and other salaried persons.....	23	2.2	15	1.7
Physicians, dentists, and veterinarians.....	14	1.3	14	1.5
Capitalists with no other occupation.....	11	1.1	11	1.2
Mechanics and small shopkeepers.....	11	1.2	12	1.2
Stock buyers.....	11	1.2	2	.2
Lawyers.....	9	.9	9	1.0
Miscellaneous urban occupations.....	12	1.3	9	1.0
Total known occupations.....	1,013	100.0	910	100.0
Unknown, joint or mixed occupations.....	22		14	
Estates sold for settlement.....			14	
Total farms.....	1,035		938	
Total rural occupations.....	727	71.8	651	72.3
Total urban occupations.....	286	28.2	259	27.7

^a Persons retired are classed according to their former occupations.^b The percentages are based on the total of known occupations.

One of the most striking facts indicated by the table is that farmers were apparently more active as buyers than as sellers of farms, constituting 65.3 per cent of the buying class and only 57 per cent of the selling class. On the other hand, retired farmers were very much more active as sellers than as buyers, while the same tendency was true of real estate men. Bankers, merchants, and stock buyers bought more extensively than they sold. Eighty-three per cent of the sales were made by three classes—farmers, retired farmers, and real estate men, while nearly 80 per cent of the purchases were made by these classes.

INTENTIONS OF BUYERS WITH RESPECT TO FARMS BOUGHT.

In order to ascertain to what extent the purchases and sales were of a speculative character, the buyers were asked to indicate their intentions with respect to disposition of the farms bought, and sellers were asked their principal reasons for selling. Table VI summarizes the results of the first inquiry. The various answers are classified in eight groups. Of the total of 988 cases in which the intentions of buyers were indicated it appears that 665, or practically two-thirds, had bought without intention of reselling, while 244, or a little more than one-fourth, bought with the definite intention of reselling. Ninety-nine, or about 10 per cent, bought with the intention of reselling, if possible, but with the expectation of operating or renting the farms in case they did not succeed in selling under favorable conditions. Probably the majority of this last-mentioned group bought for speculative motives and desire to resell rather than to retain the property for permanent investment.

TABLE VI.—*Intentions of buyers with respect to farms bought.*

A. DEFINITE INTENTIONS.		B. INDEFINITE INTENTIONS	
To rent:		Resell or rent.....	90
To rent.....	111	Resell or occupy.....	2
As investment.....	50	Operate or resell.....	5
Operate with renter.....	1	Speculation or a home.....	1
For a home on retiring.....	1	Sell one-half and occupy remainder.....	1
Total.....	163	Total.....	9
To operate:		Not for resale, but uncertain tenure:	
To occupy.....	359	Perhaps to occupy.....	2
Operate with home farm.....	13	To retain.....	6
To operate.....	56	Develop and improve.....	1
Add to farm.....	9	Total.....	9
Stock with cattle.....	1	Uncertain or unknown:	
Pasture next year.....	2	Continue operating farm in Minnesota.....	1
Operate with hired help.....	6	Buy more land.....	1
Operate with sons.....	1	Uncertain.....	3
Settle in county.....	1	Unknown.....	20
Continue operating as owner.....	1	Total.....	25
Total.....	449	Total, all cases.....	1,011
For relatives:		Known intentions.....	986
Operate by relatives.....	22		
Bought for children.....	20		
Total.....	42		
To resell:			
Resell.....	27		
Speculate.....	194		
Has been resold.....	3		
Total.....	224		

TABLE VII.—*Classification of motives for sale.*

To realize speculative profit:		Reduce holdings of farm land—Continued.	
For profit.....	47	Continue on another farm.....	20
Had held as investment.....	117	Has other farms.....	1
Good sale.....	72	Sold part, continue on rest.....	3
For speculation.....	40	Continue on home farm.....	5
Total (30 per cent).....	276	Continue on own farm.....	4
Because of retirement from farming:		Total (4.6 per cent).....	42
Already retired.....	71	Financial difficulties:	
To retire.....	161	Forced sale.....	1
To move to town.....	9	For interest.....	2
Health failed.....	3	Pay debts.....	5
Couldn't give farm attention.....	1	Obtain money.....	2
Get rid of responsibility.....	2	Clear up business.....	2
Engage in other business.....	2	Total (1.3 per cent).....	12
Total (27.1 per cent).....	249	Unsatisfactory character or location of farm:	
To buy other farm property:		Unimproved and undesirable for renting.....	1
To buy again.....	191	Get land near together.....	1
Has already bought.....	4	Total.....	2
Total (21.2 per cent).....	195	Change type of investment:	
To settle or divide estate of partnership:		Go out of land business.....	6
Settle or divide estate.....	46	Retire from banking.....	1
Dissolve partnership.....	4	Use money otherwise.....	14
Divide interest.....	30	Prefer interest to rent.....	8
Settle business.....	1	Change investment.....	3
Total (8.8 per cent).....	81	To rent.....	10
Residence in another district:		Total (4.2 per cent).....	42
Lives in another State.....	12	Alternative motives:	
Move away, change location, or transfer residence.....	5	Buy again or retire.....	2
Total (1.9 per cent).....	17	Rent or buy again.....	1
Reduce holdings of farm land:		Total.....	3
Reduce holdings.....	8	Vague, undecided, or unknown.....	45
Buy on smaller place.....	1	Total cases.....	964
		Total known.....	919

Table VII presents a classification of the alleged motives of sellers in making sales of their farms. It is undoubtedly true that motives were in many cases mixed. Even when the motive given was the desire to retire from farming, to reduce the size of holdings, or some other reason, it is probably true that the making of the sale at the particular time was due to the favorable prices for farm land. However, back of this immediate motive was often some special reason for selling. In only 276 cases out of 919, or 30 per cent, was the primary motive given as the desire to realize a speculative profit. Even in this group only 40 sellers specifically asserted that they had sold for speculation. However, several other types of answers may be interpreted as indicating the desire for speculative profit as the principal motive. In 117 cases the sellers classed in this group asserted that they held the land as an investment, but gave no other reason for selling. It is assumed that they sold because of the opportunity of making a satisfactory return from the increase in value of the land, since they had abandoned their original intention of retaining the farm for investment.

One hundred and ninety-five sellers, or 21 per cent, assigned as the principal motive the desire to buy other farm property. It is probable that some of these sellers sold their farms in order to buy other farms that suited them better, either in size, quality of soil, location, or improvements. However, it is also probable that a very large number of these sellers who asserted that they were selling in order to buy again were simply speculating in farm land. They probably sold to realize a profit and bought again for the same purpose. Consequently a considerable number of this group belong to the class of persons who were selling for speculative reasons.

In 42 cases, or 4.6 per cent of the total, the alleged motive was the desire to reduce the holdings of farm land or to dispose of some of the holdings while retaining other land. However, a considerable number of answers in this group indicate that the desire was not so much to reduce the holdings as to take advantage of the opportunity of selling a portion of the holdings at high prices. Consequently some of this group belong in the speculative class.

Two hundred and forty-nine, or 27.1 per cent, of the total gave as their motive the desire to retire from farming. Probably most of these persons had been intending to retire at some time and seized the favorable opportunity of high prices of farm land to fulfill their intentions. The high prices for land made it possible for some to get enough for their farms to retire on, whereas otherwise they would not have been able to do so. Unquestionably, therefore, the large increase in the prices for land facilitated the tendency toward retirement from farming.

Eighty-one sales, or 8.8 per cent, were made primarily for the purpose of settling or dividing estates or partnerships. It is probable that most of these farms would have been sold sooner or later to accomplish the purpose alleged, but it was thought desirable to take advantage of favorable prices. Similar to this is the group of sales classed under "financial difficulties," although the number of these sales is small.

It is necessary to consider Tables V, VI, and VII together in order to determine their probable significance. It seems clear that the high prices of the "boom" period resulted in the sale of a larger number of farms by nonfarming classes than were purchased by these classes. The temporary agricultural prosperity born of war prices resulted in more farms being acquired by farmers, both owners and tenants, than were sold by farmers. Consequently it is probable that as a result of the tendency for absentee owners of farms to unload their holdings at "boom" prices, an immediate result of the "boom" will be an increase in the proportion of farms operated by owners.

This conclusion is further strengthened by the fact that of the number of buyers who definitely indicated their intentions, excepting those whose intentions were to resell, about two-thirds indicated that they would operate their farms rather than rent them to others. On the other hand, of the farms sold, 54 per cent had been operated by tenants before sale. In 1915 the Iowa State census showed the percentage of tenancy for the State to be 41. It is highly improbable that the percentage of farms operated by tenants increased from 41 to 54 during the 4-year period 1915 to 1919. Consequently the conclusion seems justified that a larger proportion of farms operated by tenants were sold than was the case with farms operated by owners, another indication of the tendency of nonfarming owners to unload during the "boom."

DIVISION OF INCREMENT BETWEEN DIFFERENT CLASSES.

An analysis of the total increase in value from the sale of farm lands was made for 392 cases in 22 counties. The total increase in value for these cases was \$7,038,346. Of this increment \$3,327,084, or 47 per cent, was received by people dwelling in towns or cities, while \$3,711,262 was received by people dwelling in the country. However, these increments of value represented the difference between the price at the time of sale and the price at which the farm was bought, no matter how long ago the purchase was made. If we isolate the cases in which the property was purchased since March 1, 1918, and the sales effected during the period of the "boom," the total increment is \$1,036,582. Of this amount \$718,030, or

69.3 per cent, was received by dwellers in towns and cities, while \$318,552 went to dwellers in the country.

It appears, therefore, that during the period of unusual activity the larger proportion of the gains made by purchase and sale were received by urban dwellers.¹ The division of increment for all sales, no matter when the purchase was made, probably represents pretty closely the normal ratio of the shares of the urban and rural classes in the increment of value, although probably to some extent affected by the larger share of urban dwellers in purchases and sales effected during the period of unusual activity. Assuming that the cases studied with respect to the division of increment represent a fair sample of the trend for the entire State of Iowa, and that the proportion of farms sold was 8.9 per cent, as shown by general inquiry in the 60 counties studied, we may estimate the total increase of value actually appropriated by sale and divided between urban and rural dwellers during the period of recent activity at \$193,255,373. Of this amount urban dwellers received \$90,830,025, while rural dwellers received \$102,425,348.

In addition to the increment appropriated by nonrural classes as a result of the "boom," there also must be reckoned the gains of real estate men in commissions on sales made. Of 945 sales, 687, or about 73 per cent, were effected through an agent. The generally prevailing rate for farm sales appears to have been \$2 an acre. Since the acres were very much higher in value than before the "boom," this would not constitute as large a percentage on the sale as formerly. There were also, of course, some variations from this rate. The average percentage of agents' commissions on the value of sales for which records were obtained was 1.61. The total appropriated by this class through commissions alone was probably above \$3,000,000.

TERMS OF SALE.

In order to determine the probable consequences of the marked increase in farm land values and of the speculation in farm land, it was considered important to ascertain the terms of sale. Obviously, if the increase of value is abnormal the consequences will be more serious if a large element of credit has entered into the purchase of the land.

¹ There is some possibility of slight exaggeration in the percentage received by persons dwelling in towns and cities, on account of the fact that the records of sales were obtained by inquiry from persons dwelling in towns, and to some extent may have resulted in a larger proportion of cases of purchase and sale by town people than would be true if the inquiry had been carried into the rural districts. However, since a very large proportion of the farmers made their sales through agents or obtained the assistance of bankers and lawyers in towns in making their transfers, it is probable that the margin of error due to this cause is not very great.

PAYMENT AT TIME OF SALE.

It was found that the terms of sale tended more or less to conform to established custom which prevailed in the period before the "boom." In the Corn Belt it is a general practice to give possession of farms both to purchasers and to lessees on March 1. Accordingly, at the time of purchase a small cash payment is made to bind the sale, and the greater part of the cash payment is made on March 1, when possession of the farm is given.

Only about 5 per cent of the sales involved an initial payment of as much as 50 per cent of the purchase price. Nearly 95 per cent of the purchasers paid 10 per cent or less, while nearly three-fourths paid 5 per cent or less.

CASH PAYMENT MARCH 1, 1920.

Of a total of 918 sales 865 involved a cash payment March 1, 1920, averaging 33.3 per cent of the total sale price. The remaining 53 sales were cases involving full cash payment at time of sale or the initial cash payment plus the mortgage indebtedness left nothing to be paid March 1. Of the 865 cases involving a March 1 settlement, about 37 per cent agreed to pay less than 25 per cent of the purchase price March 1, 1920.

If we add the initial cash payment to the cash payment due March 1, we obtain what may be considered the total amount of cash, as distinguished from indebtedness, involved in the terms of sale. This total cash payment averages 40.7 per cent of the total consideration involved.

TABLE VIII.—*Total cash payment, including initial and March 1 payments.*

Number of farms purchased.	Per cent of purchase price to be paid in cash.	Per cent of all farms purchased.
87	100.....	9.3
238	50 and under 100.....	25.7
340	25 and under 50.....	36.7
262	25 and less.....	28.3

As shown in Table VIII, more than one-fourth of the total sales involved a cash payment of less than 25 per cent, while nearly two-thirds of the sales represented cash payments of less than 50 per cent.

MORTGAGE INDEBTEDNESS.

The sales involving one or more mortgages were 839 out of a total of 927. The average of all classes of mortgages is 64 per cent of the sale price of the farms mortgaged. As shown in Table IX, a considerable number of buyers, about one-eighth of all, have incurred indebtedness amounting to as much as 80 per cent or more of the purchase price,

while somewhat more than half the purchases involved indebtedness of 65 per cent or more.

In the great majority of sales involving a mortgage there was only a first mortgage. In many cases, even when the amount of mortgage indebtedness was greater than 50 per cent of the sale value, the entire indebtedness was carried on a first mortgage. Since the established credit agencies will not ordinarily lend on so large a margin of the value of a farm, such mortgages were usually carried by the seller. Out of a total of 820 first mortgages it was found that 141 were for 75 per cent or more of the sale price, while 536 were for 50 per cent or more, the average of all first mortgages being 56.4 per cent. About one-fourth of the sales involved a second mortgage, which averaged 32.2 per cent of the sale price. In 10 cases the second mortgage covered 60 per cent or more of the purchase price, and in 68 cases 40 per cent or more of the purchase price. Such cases, however, probably represent instances where an existing first mortgage had been arranged with some credit agency at a lower level of value and the seller found it necessary to assume a very large part of the increase of value as well as a considerable margin of the old value by taking a second mortgage.

Table X is a summary of the duration of loans in the case of 701 first mortgages for which this information was obtained.

TABLE IX.—*Number of purchases involving mortgage indebtedness, classified by per cent of indebtedness to purchase price.*

Number of farms purchased involving mortgages.	Per cent of mortgage indebtedness to purchase price.	Per cent of all farms purchased.
110	80 or more.....	13.1
333	65 and under 80.....	39.7
265	50 and under 65.....	31.6
131	Less than 50.....	15.6
839	-----	100.0

TABLE X.—*First mortgages, classified by duration of loan.*

Number of years to run.	Number of mortgages.	Number of years to run.	Number of mortgages.	Number of years to run.	Number of mortgages.	Number of years to run.	Number of mortgages.
1	6	5	246	10	241	16	3
2	12	6	15	11	5	20	9
3	35	7	27	12	4	25	1
4	27	8	27	14	1	30	1
4½	1	9	11	15	26	33	3

It appears from Table X that there is a strong tendency to make mortgages either for 5 years or for 10 years, nearly 70 per cent of the first mortgages being about equally divided between these two periods.

Following is a summary of rates of interest on first mortgages:

At $4\frac{1}{2}$ per cent.....	1	At $5\frac{1}{2}$ per cent.....	391
At 5 per cent.....	307	At $5\frac{3}{4}$ per cent.....	1
At $5\frac{1}{4}$ per cent.....	4	At 6 per cent.....	76

It seems clear that practically all mortgages are either for 5 per cent, $5\frac{1}{2}$ per cent, or 6 per cent, those made at $5\frac{1}{2}$ per cent predominating, closely followed by those made at 5 per cent.

The duration of second mortgages is shown in table XI.

TABLE XI.—*Second mortgages classified by duration of loan.*

Number of years to run.	Number of cases.	Number of years to run.	Number of cases.
2	4	8	5
3	14	9	2
4	7	10	28
$4\frac{1}{2}$	1	12	3
5	17	15	6
6	2	20	1
7	6	33	1

As in the case of first mortgages, 5 years and 10 years are the outstanding periods. The average duration for second mortgages is 6.6 years as compared with 7.7 years for first mortgages.

Rates of interest on second mortgages are as follows:

At 5 per cent.....	31	At 7 per cent.....	4
At $5\frac{1}{2}$ per cent.....	56	At 8 per cent.....	3
At 6 per cent.....	79		

There seems to be a stronger tendency toward a 6 per cent rate than in the case of first mortgages. However, the rate of interest for second mortgages is not to a marked extent greater than for first mortgages, the average being 5.7 per cent for second and 5.3 per cent for first mortgages.

A few third mortgages were found, numbering, in all, 11. Four of these were for 4 years, 5 for 5 years, 1 for 6 years, and 1 for 8 years. Seven were given at 6 per cent, 3 at $5\frac{1}{2}$ per cent, and 1 at 5 per cent.

A study of the terms of the loans indicates that on the whole they are not more liberal in percentage of cash payment required on purchase price than was the practice before the "boom." One of the authors of this bulletin has made a comparative study of terms of loans covering both periods¹ and has found that the percentage of average sale value required in cash during 1919 corresponds very closely to the percentage required in the period before the "boom." There appears to be a strong tendency toward conventional rates of interest and periods of loans.

¹ "Studies of Land Values in Iowa," by O. G. Lloyd, the *Iowa Agriculturist*, December, 1919, page 361.

There are enough deals on narrow margins of cash and at substantial rates of interest to cause considerable trouble if fundamental conditions should become unfavorable to agriculture in the near future. It may be a matter of some concern, considering the high levels of value characterizing these purchases and the great uncertainty as to the future course of prices of agricultural products, that more than one-fourth of the sales were effected on a total cash payment of 25 per cent or less, while nearly two-thirds of the cases involved cash payments of less than 50 per cent; that the average mortgage indebtedness incurred is 64 per cent of the sale price, and in 110 of the cases involving mortgages it is 80 per cent or more of the sale price; that one-fourth of the sales involved second or third mortgages, and that a considerable majority of the mortgage indebtedness is contracted at rates of interest amounting to $5\frac{1}{2}$ per cent or more, whereas the ordinary rate employed in calculating farm labor income is 5 per cent.

LEGAL CHARACTER OF CONTRACTS.

No systematic and comprehensive study of the legal character of contracts was made with a view to determining the relative number of the different kinds of contracts, but by general inquiry various methods employed were ascertained and certain conclusions may be drawn therefrom.

Generally speaking, there was no extensive buying and selling of mere options of purchase. It is indeed fortunate that the methods employed were not carried to this extreme.

The great majority of the contracts were contracts of specific performance, that is, the seller agreed to deliver possession and title of a specific piece of land in substantially the same condition as at time of sale, meanwhile keeping buildings, fences, and other improvements insured and repaired. The delivery of title was made contingent upon the making of certain cash payments and the assumption of certain other obligations on the part of the buyer. For the most part, as already noted, the delivery of title and possession was to take place on the March 1 subsequent to the making of the contract, and at that time the buyer was to make a substantial cash payment upon the land and at the same time to assume formally such indebtedness as had been agreed upon.

Generally, in case of subsequent sale before acquisition of title, the former purchaser entered into a formal contract of sale with the new purchaser, although not yet the holder of the title which he agreed to transfer. In some cases a series of these contracts of sale were made for the same piece of land.

The fact that the contract called for specific performance in the delivery of a particular piece of land is of significance because if for any reason one of the parties to any of the series of contracts failed

to carry out his part of the contract, the fulfillment of all subsequent contracts would necessarily be defeated. For instance, if the first buyer of a farm failed to obtain title because of his inability either to make the necessary cash payments or to get valid title, he would be unable to fulfill his contract of sale with the second buyer, who, in turn, would find it impossible to carry out his contract of sale with the third buyer; and so on throughout the series. Unless the matter could be settled by mutual agreement, the recourse of the several parties who have purchased the right to receive title to the land would be a suit to enforce performance and action for damages in case of nonfulfillment. Consequently such a situation involves the possibility of considerable litigation as well as a large degree of financial uncertainty for the parties concerned.

In some instances contracts call for the specific forfeiture of the purchaser's initial payment in case of his failure to perform his part of the contract. Generally, however, the seller retained the alternative right of compelling the purchaser to complete the cash payments agreed upon. Usually the contracts did not include a clause involving a waiver of performance on forfeiture of initial payment.

In some cases legal methods of dubious character from an ethical point of view were employed for the purpose of reducing the liability and risk of the speculator. Two principal methods appear to have been used for these purposes. The first consisted of the formation of a corporation with limited liability for the purpose of buying and selling farm lands. The members of these corporations bought land under ordinary contracts of sale, using the greater part of the capital for the purpose of making initial payments with the intention of reselling the land at a profit. However, in case the land failed to advance in value and the buyers found themselves overloaded, the liability would be limited to the assets of the corporation and the individual assets of the stockholders would be immune. A second method was the employment of a "dummy" buyer. The real buyer bought the land in the name of another person who possessed no valuable assets. The "dummy" then assigned his rights of purchase for a nominal consideration to the real buyer, while still retaining the obligations contained in the contract. The assignment was commonly expressed as follows: "For and in consideration of the value received I hereby sell, assign, transfer, and convey to John Doe my rights of purchase in and under the attached contract." Apparently such a clause attached to a contract of sale conferred upon the person mentioned in the clause the right to complete the original contract without obligating him to pay or be held accountable to the first seller for the terms of the contract.

In some cases, real estate men, not satisfied with regular commissions, introduced a dummy buyer as a means of sharing the incre-

ment. Having obtained the listing of a farm at a certain minimum price and having found a purchaser at a considerably higher price, the real estate man might arrange a sale to a friend at the minimum price with the understanding that the profit derived from the subsequent sale would accrue to the real estate man and his friend.

FARM EARNINGS AND INCOMES OF OWNERS, TENANTS, AND LANDLORDS, 1913, 1915, 1918, 1919.

The value of the farm is so large a part of the total capital employed in farming that a considerable change in that value must have a profound influence on the incomes of owner operators, tenants, and landlords. In order to measure the effects of the radical change in land values in the past few years on the several classes of incomes, data on farm earnings and incomes have been assembled by the survey method for three different years, 1913, 1915, and 1918, and covering the same areas in each of two years.

The two districts studied in this manner are shown by solid black areas on the map, figure 1. One of the districts consists of contiguous townships in Tama, Blackhawk, and Grundy Counties. Since the majority of the farms surveyed in this district are in Tama County, the district will be referred to hereafter as the "Tama" district. Data on farm earnings were obtained for 965 farms in this district in 1913 and for 211 farms in 1918. The other district lies wholly in Warren County, principally in the southern portion of the county. Data on farm earnings were obtained for 832 farms in this district in 1913 and for 183 farms in 1918.

The two districts differ considerably in character. Measured both by value of land per acre and by farm income per acre, the Tama district is shown to be characterized by more productive land than the Warren district. The average size of farms is greater in the first district, and the percentage of tenanted farms of the total number surveyed greater—46 per cent as compared with 31 per cent in the Warren district. Finally, farm earnings in the Warren district were considerably reduced in 1918 because of an unusually poor crop of corn. This fact is reflected in all comparisons of incomes for the two districts. Because of these contrasts the data are presented separately for the two districts. These data are presented from several standpoints.

In order to interpret correctly the significance of these changes in income it is necessary to consider, not only the changes measured in dollars, but also changes in the purchasing power of the dollar for the period covered. Unfortunately there are no detailed statistics on farmers' budgets that are adequate for the purpose of weighting changes in prices according to the relative importance of the several items in the farmer's budget. According to the index numbers of the United States Bureau of Labor, wholesale prices increased 123

per cent from 1913 to October, 1919. However, the estimated increase in retail prices, weighted according to the relative importance of the various articles in the family budgets of urban populations, was only 83.1 per cent. There is no reason to believe that the prices of commodities bought by farmers have increased at a lower rate, especially, as there has been a general increase in the level of prices since October, 1919. It is probable that a 100 per cent increase from 1913 to January, 1920, is a conservative estimate of the increase in the cost of maintaining the farmers' budget of 1913.

The same comparison substantially applies to the period from 1915 to 1920, for average wholesale prices increased only 3 per cent from 1913 to 1915.

FARM INCOME ON FARMS CLASSIFIED BY TENURE.

The questions to be first considered are: (1) What increase has occurred in the earning power of farms as a result of increased prices of farm products and other causes? (2) Has this increase in earning power been greater or less in proportion than the increase in the average value of land?

These questions may be answered by comparing the increase of farm incomes with the increase of land values for the corresponding periods. By farm incomes is meant the difference between the farm receipts and expenses for the year, plus any gain or minus any loss from inventory. No deduction is made for the interest on the capital employed or for the value of the farmer's labor and for his uninsured risk.

TABLE XII.—*Farm incomes for farms classified by class of tenure.*

I. TAMA DISTRICT.

Tenure.	Number of farms.		Average farm income.		Average farm income per acre.		Per cent increase per acre.	Average value of land per acre.		Per cent increase over—	Average size of farm.	
	1913	1918	1913	1918	1913	1918	1913	1913	1918	1913	1913	1918
All farms.....	965	211	\$2,607	\$4,570	\$12.59	\$20.79	65.1	\$197	\$239	21.3	<i>Acres.</i> 207	<i>Acres.</i> 219.8
Owners.....	308	86	2,471	4,272	13.14	19.33	47.1	206	241	17.0	188	221.0
Owners additional ^a	154	28	3,121	4,951	12.95	23.85	84.1	197	243	23.3	241	207.6
Tenants.....	503	97	2,533	4,721	12.18	21.22	74.2	192	236	22.9	208	222.5

II. WARREN DISTRICT.

	1915	1918	1915	1918	1915	1918	1915	1915	1918	1915	1915	1918
All farms.....	832	183	\$1,454	\$2,241	\$9.32	\$12.67	35.9	\$117	\$145	23.9	156	176.9
Owners.....	345	84	1,270	1,997	8.58	11.63	35.5	119	148	24.3	148	171.6
Owners additional ^a	190	43	1,630	2,673	9.94	13.75	38.4	117	146	24.7	164	194.4
Tenants.....	297	56	1,556	2,273	9.73	13.26	36.2	116	139	19.8	160	171.4

^a Owners who rent additional land.

In Table XII it will be noted that average farm incomes for owners and tenants of the Tama district nearly doubled between 1913 and 1918. The increase per acre was somewhat less, because there was a considerable increase in the average size of the farms both of owners and of tenants. The percentages of increase of farm income per acre were 47 for owners, 84 for owners additional, and 74 for tenants. For all farms the increase in farm income per acre was 65 per cent. In contrast with these rates of increase in farm income average land values of these farms increased only from 17 to 23 per cent during the same period. In the Warren district the percentages of increase in farm income as compared with the percentages of increase in land value were not so marked because of the fact, already noted, that in this district the corn crop of 1918 was far below normal. Yet, even under these unfavorable conditions the percentages of increase in farm income were larger than the percentages of increase of land value, the former averaging 36 for all classes of farms as compared with 24 per cent for the latter.¹

These facts appear to indicate that up to 1918 the increase of Iowa land values had lagged behind the increase of average farm income, and there can be little doubt that this created a favorable condition for the sudden and rapid advance in land values during 1919 and the accompanying "boom."

For the years studied, and in both districts, "owners additional" (those who rent land in addition to their own holdings) made a larger average farm income than either owners or renters. Moreover, owners appear the least efficient of the three classes, whether efficiency is measured by total farm income or by farm income per acre, with the single exception of 1913 in the case of farm income per acre (refers to Tama County).

FARM LABOR INCOME CLASSIFIED BY TENURE.

In farm income, as discussed above, no allowance is made for the annual interest on the value of capital employed, including the value of the farm. To whatever extent a farmer borrows the capital employed, he must pay interest out of the income from the farm. If he employs his own capital, he should receive a return for it corresponding to what he could get in other kinds of investment. In farm economic studies it has been generally customary to consider 5 per cent a reasonable allowance for the use of capital in farming. It should be recalled, however, that of the recent sales of farms a large number were made on the basis of mortgages bearing 5½ per cent. Moreover, for short-time loans obtained from banks, the

¹ This increase in farm values for the Tama district is considerably smaller than that indicated by statistics of the Census and Bureau of Crop Estimates, which for the entire State was about 40 per cent from 1913 to 1918.

Iowa farmer pays not less than 6 per cent and commonly 8 per cent. It is also important to recognize the fact that although farmers can obtain at least 5 per cent for their own capital at the present time by investing in bonds of undoubted security, they have largely preferred to invest in land yielding an annual return, not counting increase of value, of much less than 5 per cent.

Table XIII shows the farm labor income at different periods; that is, what is left to pay for the labor and risk of the farm operator after charging the farm with the use of the capital employed. This charge is made both at 5 per cent and at $5\frac{1}{2}$ per cent. In order to determine the effect of increased value of land on farm labor income, these percentages are calculated both on the value of total capital in March, 1918, and on the value of total capital in August, 1919. The farm income in both cases is that of 1918, a year characterized by normal production in one of the districts, as well as by the high level of war prices for farm products; therefore, in at least one district, a year as favorable from the standpoint of income as the farmer may expect in the near future.

TABLE XIII.—*Farm labor income classified by tenure, 1913, 1915, 1918, 1919.*

TAMA DISTRICT.

Tenure.	Number of farms.		Farm labor income after charging 5 per cent for capital. ^a			Farm labor income after charging $5\frac{1}{2}$ per cent for capital. ^a		
	1913	1918	1913	1918	Aug., 1919.	1913	1918	Aug., 1919.
All farms.....	965	211	\$306	\$1,537	\$222	\$75	\$1,234	b—\$213
Owners.....	308	86	253	1,166	b—148	32	855	b—590
Owners additional.....	154	28	435	2,030	642	167	1,737	210
Tenants.....	503	97	298	1,723	429	74	1,423	b— 1

WARREN DISTRICT.

	1915	1918	1915	1918	Aug., 1919.	1915	1918	Aug., 1919.
All farms.....	832	183	\$370	\$746	\$69	\$262	\$597	b—\$149
Owners.....	345	84	212	506	b—207	106	357	b—427
Owners additional.....	190	43	495	1,017	335	382	851	101
Tenants.....	297	56	474	897	275	366	759	75

^a In this table and subsequent tables the investment value per farm for 1918 is that of March 1 and that of 1919, Aug. 1. The value at a particular time, rather than the average value at beginning and end of the fiscal year, is employed because of the marked changes in farm land value during the period and in order to show the effect of these changes on incomes. For 1913 and 1915 the usual method of averaging values at beginning and end of year is employed.

^b Loss.

On the basis of land values in 1918, farmers of all classes of tenure in the Tama district made farm labor incomes averaging \$1,537 for all farms, after deducting 5 per cent on the value of all farm capital, including the value of land, whereas in 1913 the average for all farms was only \$306. Even charging $5\frac{1}{2}$ per cent on the value of

farm capital, the farm labor incomes averaged \$1,234 as compared with \$75 in 1913. These labor incomes may be compared with the estimated value of the time spent by the farmers in labor and superintendence. In 1913 this averaged \$719, or \$413 more than the average farm labor income calculated at 5 per cent, and \$644 more than the farm labor income calculated at $5\frac{1}{2}$ per cent. In 1918 the estimated value of farmer's labor and superintendence was \$1,169. Consequently, the farmers of this district made labor incomes which, calculated at 5 per cent, averaged \$368 more than the value of labor and superintendence. When calculated at $5\frac{1}{2}$ per cent the excess of labor incomes above the value of labor and superintendence averages \$65.

When calculated on the basis of a 5 per cent deduction for capital, the farm labor incomes of the Tama district in 1918, as compared with those of 1913, increased several hundred per cent. Thus, the farm labor incomes of owner operators were 361 per cent higher; those of owners additional, 367 per cent higher; and those of tenants, 478 per cent higher than in 1913. Even making allowance for the decline in the purchasing power of the dollar, there can be no doubt that the farmers of this district earned a considerably larger return for operator's labor and risk than in 1913, a larger return attributable to the favorable combination of good crops, high prices for farm products, and land values that had not yet advanced in proportion to farm income.

In the Warren district the increase in farm labor income is not so marked on account of the poor crop season. Nevertheless, the increase in this district ranges from 89 per cent for tenants to 139 per cent for owners.

If farm labor income be calculated by charging $5\frac{1}{2}$ per cent instead of 5 per cent for the use of capital, the average farm labor income for each of the several classes of tenure in the Tama district is, of course, smaller than when capital is charged only 5 per cent. However, the increase in percentage as compared with 1913 is even greater than when calculated on the 5 per cent basis, for the higher rate charged for capital accentuates the relative advantage of 1918 due to the failure of land value to increase in the same proportion as farm income. Thus, in the Tama district the average farm labor income was about sixteen times as great in 1918 as in 1913. This result may be expressed in another way by saying that it was impossible for the average farmer to pay $5\frac{1}{2}$ per cent for all of his capital in 1913 and have any considerable remainder for his own time and risk, while the proportionately greater increase of farm incomes of 1918 as compared with the increase of land values enabled the farmer to pay $5\frac{1}{2}$ per cent on capital and still have a substantial remainder.

The same tendencies prevailed in the Warren district, though the increase in farm labor income was on a much smaller scale.

When farm labor incomes are calculated on the basis of the land values of August, 1919, the situation is entirely changed. The deduction of 5 per cent for the use of capital results in a minus labor income of \$148 for owners in the Tama district and a minus labor income of \$207 for the same class in the Warren district. In the Warren district the average labor incomes of farms of the several classes of tenure were actually less than in 1915, while in the Tama district the average for all farms is somewhat less than in 1913. In the Tama district farm labor incomes of owners additional and tenants, on the basis of land values of August, 1919, are about 50 per cent higher than in 1913; an increase however, that is not as great as the decline in the purchasing power of the dollar from 1913 to 1919. Consequently the labor incomes of 1913 represented a greater amount of purchasing power than those based on land values of August, 1919.

It is well to pause in the presentation of these facts to emphasize their significance.

It is apparent that the level of land values prevailing in 1919 was too high to make it possible to pay 5 per cent on these values and still to earn a fair return for the labor and risk of the farmer. This was especially true of farms operated by owners, which make a poorer showing than the farms operated by other classes of tenure—a result which is also shown by the statistics of 1913 and 1915. Consequently, under these conditions, the average farm owner in this area who operates his farm must be willing to take a lower return than 5 per cent on the market value of his farm or to give his own time for less than nothing. In case a large part of the capital is borrowed at interest rates of $5\frac{1}{2}$ to 6 per cent, the financial outlook for such a farmer is not a promising one.

It may be said that the income considered is that of 1918, while the land values are those of 1919. However, it is probable, as already stated, that in the Tama district the good yields and unusually favorable prices of 1918 resulted in incomes as high as may be expected for some years. Furthermore, recent data indicate lower farm labor incomes for the crop year 1919 than for 1918.

OPERATORS' LABOR INCOMES OF TENANTS AND OWNERS ADDITIONAL.

In Table XIII, above, farm labor incomes were calculated on the basis of allowing 5 per cent or $5\frac{1}{2}$ per cent for the use of all capital employed, including the value of the land. Tenants, however, obtain the use of the land by paying rent rather than by paying a certain rate of interest on the value of the land, while owners additional obtain a part of their land by payment of rent.

In the State of Iowa net rent from farms tends to be less than 5 per cent on the average value of farm land and improvements. Data concerning rents were obtained for 238 farms in 49 Iowa counties,¹ and these data are summarized in Table 14.

TABLE XIV.—Average rentals on 238 Iowa farms, 1918; percentage of average net rentals to average value of farm land and improvements, Mar. 1, 1918, and Mar. 1, 1919.

	Cash.	Share cash.	Share.	All farms.
Average gross rent per acre.....	\$6. 37	\$11. 84	\$12. 28	\$8. 53
Average net rent per acre.....	\$4. 72	\$9. 51	\$10. 21	\$6. 63
Average value of land and improvements per acre:				
Mar. 1, 1918.....	\$181. 30	\$206. 22	\$204. 64	\$190. 94
Mar. 1, 1919.....	\$207. 61	\$236. 19	\$228. 57	\$218. 33
Per cent of average net rent, 1918, to average value of land and improvements:				
Mar. 1, 1918.....	2. 71	4. 96	5. 29	3. 47
Mar. 1, 1919.....	2. 35	4. 33	4. 73	3. 03
Number of farms.....	145	79	14	238

As shown by Table XIV, the percentage of net rent is less than 5 in all systems of renting except in the case of the percentage of stock share rentals to land values of 1918, and that in a year when crop conditions and prices in the State were favorable to substantial returns under the share systems of renting.²

TABLE XV.—Operators' labor income.

TAMA DISTRICT.

Tenure.	Number of farms.		Operators' labor income.		Operators' labor income per acre.	
	1913	1918	1913	1918	1913	1918
Owners.....	308	84	\$253	\$1,166	\$1.35	\$5.28
Owners additional.....	154	28	961	2,129	3.99	10.26
Tenants.....	503	97	1,815	3,053	6.32	13.72

WARREN DISTRICT.

	1915	1918	1915	1918	1915	1918
Owners.....	345	84	\$212	\$506	\$1.43	\$2.86
Owners additional.....	190	43	548	1,012	3.34	5.21
Tenants.....	297	56	725	819	4.53	4.78

If, in calculating the labor incomes of tenants and owners additional, the actual rent of leased land be deducted, instead of 5 per cent on the value of the land, the result may be quite different from that obtained in calculating farm labor incomes by deducting 5 per cent on the value of all capital. In Table XV, tenants are charged

¹ These data are additional to those obtained for the two areas selected for intensive study.

² A survey of 114 farms in 1912 showed an average percentage of return to landlords of 3.7 for all farms, 4.1 for stock share leases, 2.3 for cash leases, and 4.1 for share cash leases.—Farm Leases in Iowa by O. G. Lloyd, Bulletin 159, Iowa Experiment Station.

with 5 per cent on operating capital and with the rent paid for use of the land. Owners additional are charged 5 per cent on operating capital and land owned by them, and with the rent of land leased. The labor incomes thus obtained are called "operators' labor incomes" to distinguish them from farm labor incomes presented in Table XIII. For purposes of comparison the farm labor incomes of owners, which are also operators' labor incomes, are included. The data for operators' labor incomes are summarized in Table XV.

The figures for operator's labor income emphasize the relative financial disadvantage under which the farmer must labor in owning the land farmed as compared with renting all or part of it, if as an owner he must charge himself with 5 per cent on the value of the land owned. The disadvantage is even greater when the charge for capital is $5\frac{1}{2}$ per cent. This relative disadvantage is especially great in the Tama district because the percentage of landlord's net rent to value of land is much less than in the Warren district. (See Table XVI.) While owners in the former district were able to earn average labor incomes of \$1,166 after deducting 5 per cent on land values of 1918, and minus \$148 after deducting 5 per cent on land values of 1919, tenants earned average labor incomes of \$3,053 after paying the rent charged. Owners additional earned average labor incomes of \$2,129 after deducting rent paid on land leased and 5 per cent on the value in 1918 of the land owned by them. The incomes of this class would have been considerably less if calculated on the 1919 value of the land owned by them.

However, these comparatively large labor incomes in the Tama district—considerably more than double those earned by the corresponding classes in 1913—are based on rents paid in 1918. It is probable that somewhat higher rents prevailed in 1919, for there are indications that rents are increasing. Not only is this conclusion justified by general reports from various sources, but it was verified by a supplementary investigation of the cash rent paid on upwards of 100 farms for lease years beginning March 1, 1918, 1919, and 1920. The average cash rent was \$7.71 in 1918, \$8.31 in 1919, and \$10.07 in 1920.

In view of the fact that tenants' average labor income in the Tama district was only 132 per cent higher than in 1913, no large increase in rent could occur in this district without lowering the relative purchasing power of the tenants' labor income; for, as shown above, the purchasing power of the farmer's dollar was probably not more than half as great in 1919 as in 1914. Moreover, 1918 was probably an unusually favorable year in yields and in prices obtained for farm products.

In the Warren district the operator's labor income of tenants, \$819, was even less than the farm labor income for this class, for the net

rent paid by tenants averaged 5.33 per cent on the value of the land in 1918 (see Table XV); whereas in 1915 the average operator's labor income of tenants was \$725. Although the small labor income of 1918 is partly due to a poor corn crop in this district, it does not appear that landlords could materially increase the rent charged without seriously reducing the labor income of the tenant.

PER CENT OF LANDLORDS' NET RETURN ON PRESENT VALUE OF INVESTMENT, AND ECONOMIC RENT.

In Table XVI is shown the percentage of the landlord's net rent to the total value of the land and buildings owned by him. The table shows also the economic rent of the land—that is, the amount that could be paid as rent if all the other factors of production were allowed just the amount necessary to obtain their services. This quantity has been calculated by deducting from farm income (1) 5 per cent on the operating capital of the farmer (excluding land value), and (2) the value of the farmer's own labor and supervision. The remainder includes only one other item besides the annual value of the land—namely, uninsured risk. Disregarding this item, the remainder may be considered as the maximum amount that may be attributed to the land without depriving the other factors of production—labor, equipment, and superintendence—of the competitive value of their services.¹

TABLE XVI.—*Landlord's per cent of net return on investment; economic rent.*^a

TAMA DISTRICT.

Tenure.	Number of farms.		Per cent of landlord's net return on farm capital.			Economic rent per acre. ^a	
	1913	1918	1913	1918	Aug., 1919	1913	1918
Owners.....	308	86				\$7.89	\$12.01
Owners additional.....	154	28	2.73	4.10	2.76	8.46	15.90
Tenants.....	503	97	2.48	2.43	1.65	7.59	14.42
Cash.....	326	76	2.15	1.90	1.30	7.43	14.62
Stock-share.....	51	7	2.82	4.03	2.82	6.74	10.06
Share-cash and share.....	126	14	3.19	4.54	3.00	8.65	15.93

WARREN DISTRICT.

	1915	1918	1915	1918	Aug., 1919	1915	1918
Owners.....	345	84				\$4.00	\$4.92
Owners additional.....	190	43	5.06	6.82	4.49	5.83	7.95
Tenants.....	297	56	3.95	5.33	3.60	5.37	6.89
Cash.....	88	9	2.95	3.13	2.09	3.92	2.53
Stock-share.....	70	16	3.85	4.24	2.98	5.87	6.95
Share-cash and share.....	139	31	4.65	6.52	4.37	5.86	8.03

^a Economic rent—the amount that could be paid as rent if all the other factors of production were allowed just the amount necessary to obtain their services.

¹ The term "economic rent" is usually employed to mean the annual economic value of the land over a period of years, taking both fat and lean years into consideration and excluding the annual value of improvements. For lack of a better term, the expression is here applied to the earnings imputable to the land in a single year, and no attempt is made to separate the values of land and improvements.

The statistics on economic rent and landlords' per cent of net return on present value of investment in Table XVI are of great interest and significance. The statistics may be considered from several standpoints.

In the first place, we may compare the increase of economic rent per acre with the increase in land value per acre for the corresponding periods. In the Tama district economic rent increased about 74 per cent for all classes of farms from 1913 to 1918, while land values increased only 21 per cent. This disparity indicates forcibly the condition that produced the radical readjustment in land values during the recent "boom." On the other hand, while the economic rent increased 74 per cent from 1913 to 1918, land values from 1913 to 1919 increased 82 per cent, indicating a tendency for the increase of land values to outrun somewhat the increase of economic rent. This tendency was particularly marked in the Warren district. As a result of the poor corn crop of 1918 economic rent for that year was only 28 per cent higher than in 1915, whereas the influence of the boom caused land values to advance 89 per cent during the same period.

The two districts present interesting contrasts in respect to the per cent of the average net return of landlords to the average value of landlords' investment. For all systems of renting the percentage of landlords' return is higher in the Warren district than in the Tama district. Thus, for all rented farms the percentage of landlords' net return in the Warren district averaged 3.95 per farm in 1915 and 5.33 in 1918, while in the Tama district the percentages are 2.48 and 2.43 for the respective periods. However, comparisons for all tenant farms are somewhat affected by the different proportions of cash and share-rented farms in the respective periods, as well as in the two districts, and safer conclusions may be derived from comparing changes in landlords' per cent of returns under the same system of renting.

In the Tama district the percentage of landlords' return on farms rented for cash slightly declined from 1913 to 1918, indicating that cash rents failed to keep pace with the advance in land values, while in the Warren district the percentage of return on cash-rented farms increased somewhat. In both districts, however, the landlords' participation in the benefits of rapidly advancing prices of products under the systems of share renting resulted in considerable increases in percentages of landlords' return on share-rented farms. Since a higher per cent of the farms in the Warren district were rented on shares than in the Tama district, this fact explains the relatively large landlords' per cent of return for all tenant farms in the Warren district.

If the landlords' per cent of return on present value of investment be calculated on the basis of the ratio of 1918 rents to the land values

of August, 1919, the percentages for various systems of renting in both districts are reduced below the percentages of 1913 and 1915, respectively, the percentage falling to 1.65 in the Tama district and 3.60 in the Warren district.

It is, of course, possible that these percentages may be increased through the increase of rent rates. The possibility of this may be determined by comparing contract rents and economic rents. This comparison is presented in Table XVII. In the last line of the table is shown the estimated rent per acre that landlords must receive in order to have as large a percentage of return on the basis of land values in August, 1919, as they received in 1913 and 1915, respectively

TABLE XVII.—*Comparison of economic rents and contract rents, all tenant farms.*

	Tama district.	Warren district.
Economic rents per acre:		
1913.....	\$7.59	-----
1915.....		\$5.37
1918.....	14.42	6.89
Net contract rents per acre:		
1913.....	4.79	-----
1915.....		4.72
1918.....	5.76	7.24
Estimated contract rent on basis of land values, August, 1919.....	8.60	11.44

The table shows that in the Tama district contract rent per acre in 1913 averaged but little more than half the economic rent, while in the Warren district contract rent per acre in 1915 was also substantially less than economic rent. The difference, of course, between economic rent and contract rent accrued to the tenant as a return for his enterprise and risk, in addition to the estimated value of his labor and superintendence. In 1918 economic rent in the Tama district had advanced to such an extent that it was two and one-half times as great as contract rent. In the Warren district, however, as a result of poor crops, contract rent was more than 5 per cent higher than economic rent. In the Tama district economic rent of 1918 is more than sufficient to pay the same rate of return on the land values of August, 1919, as prevailed in 1913, but in the Warren district the amount necessary to pay the same rate of return on land values of August, 1919, is about 66 per cent greater than the economic rent of 1918.

Even in the Tama district, however, if the landlords should receive the same percentage of return on land values of 1919 as they received in 1913, the labor income of tenants would have to be \$2.84 per acre less than it was in 1918. This would reduce the tenant's labor income to an average of \$2,421 as compared with \$1,315 in 1913. Considering the change in the purchasing power of money during the period, the tenant would probably have a smaller real income.

Whether the economic rent of 1918 may continue to be maintained depends, of course, on future yields and future prices. The former can undoubtedly be substantially increased in the Warren district, but it is at best doubtful whether the high average economic rent of the Tama district will be maintained in subsequent years.

It is not to be assumed, of course, from the above discussion that contract rent should be as high as economic rent, for the latter has been calculated by allowing the tenant only the estimated value of his labor and superintendence, with no allowance for his enterprise and risk.

PER CENT NET RETURN OF ALL CLASSES OF OPERATORS ON OPERATORS' CAPITAL.

In order to determine how profitably the farmer's capital is employed in production it is desirable to ascertain the net return on his capitalization. To determine this net return it is necessary to deduct from the average farm income the rent paid for land not owned by the operator, together with the value of the labor and supervision of the farmer. The percentage of this remainder to the farmer's capital, whether represented by land, operating capital, or live stock, may provide a measure of the return on capital for the different classes of farmers, as contrasted with the return on investments in other lines of business, and it may also afford a test of the relative profitableness of farming under different tenures. The increased value of the land is regarded as reinvested capital in the case of owners operating their farms. These facts are presented in Table XVIII.

It will be noted that on his comparatively small investment the average per cent of return of the tenant is much higher than that of either owners or owners additional. In 1913 tenants in the Tama district earned 18.3 per cent as compared with 3.98 per cent for owners and 5.6 for owners additional. In 1918 tenants in this district earned nearly 32 per cent as compared with 5 per cent for owners and 7 per cent for owners additional. In the Warren district tenants earned 12.4 per cent in 1915 as compared with 3.6 per cent by owners and 5.3 by owners additional. In 1918, however, tenants in this district made only 2.3 per cent on total capital, while owners earned 3.6 per cent on capitalization, and owners additional 5.5 per cent. The small relative return to tenants in this case is due to the large proportion of share tenants in Warren County, for all classes of share tenants paid the landlord about 5.8 per cent on the 1918 average value of the farms rented.

Although, because of their relatively small investment, the percentage of return on capital earned by tenants varies to a much greater extent than do the returns of owners and owners additional, the general tendency has been for tenants to earn a higher percentage of return on their capital than either of the two other classes.

TABLE XVIII.—*Per cent of average net returns of all classes of operators on average value of operators' capital.*

TAMA DISTRICT.

Tenure.	Number of farms.		Per cent return on operator's capital.			Average value of operator's capital.		
	1913	1918	1913	1918	Aug., 1919.	1913	1918	Aug., 1919.
Owners.....	308	86	3.98	4.99	3.50	\$44,352	\$62,132	\$88,404
Owners additional.....	154	28	5.58	7.02	4.89	16,012	45,555	65,448
Tenants.....	503	97	18.30	31.98	31.98	4,537	7,081	7,081

WARREN DISTRICT.

	1915	1918	1915	1918	Aug., 1919.	1915	1918	Aug., 1919.
Owners.....	345	84	3.63	3.59	2.43	\$21,159	\$29,823	\$44,080
Owners additional.....	190	43	5.31	5.49	3.95	16,012	24,411	34,008
Tenants.....	297	56	12.36	2.34	2.34	2,492	3,160	3,160

PRECARIOUSNESS OF FARMERS' INCOMES.

The preceding discussion of farmers' incomes is in terms of averages. From the standpoint of farmers who may be undertaking the purchase of farms on large margins of indebtedness it is important to consider not only the average incomes earned, but also what proportion of farmers were unsuccessful as measured by the failure to make a plus farm labor income. Table XIX shows the per cent of all farmers of each class of tenures making a minus labor income in 1918, and likewise on the basis of 1919 land values. The table also shows the per cent of all farmers of each class of tenure making less than the estimated average value of farmers' labor and supervision in the periods mentioned. In all cases the allowance for use of capital is 5 per cent.

TABLE XIX.—*Percentages of farmers making minus labor incomes and percentages making less than estimated average value of farmers' labor and supervision.*

District and tenure.	Per cent making minus labor income.		Per cent making less than average value of labor and supervision.	
	1918	Aug., 1919.	1918	Aug., 1919.
Tama district:				
Owners.....	22	49	57	78
Owners additional.....	11	32	46	71
Tenants.....	11	39	42	65
Warren district:				
Owners.....	32	62	73	85
Owners additional.....	19	42	56	74
Tenants.....	20	38	47	61

It is apparent that by either of the methods of measurement a larger percentage of owner operators were unsuccessful than was the case with either of the other classes of tenure. Moreover, the percentages of unsuccessful farmers by either method of measurement is higher in the Warren district, with a single exception, than in the Tama district, owing to the poor crop year of 1918 in the former district. The single exception is the per cent of tenants making a minus farm labor income on the basis of the land values of August, 1919.

The percentages of those failing to make any labor income in 1918 are not large for the Tama district, but it is a striking fact that under the favorable conditions of 1918 in that district the farm incomes based on the land values of 1919 result in minus labor incomes for 32 per cent of the owners additional, 39 per cent of the tenants, and 49 per cent of the owners. The percentages failing to earn the estimated average value of the labor and superintendence of the farmer, even on the basis of 1918 land values, range from 42 per cent for tenants to 57 per cent for owners. When calculated on the basis of 1919 land values, those failing to earn the value of the farmer's labor and superintendence constitute nearly two-thirds of the tenants and over three-fourths of the owners.

As already pointed out, it must be borne in mind that the actual conditions are not so serious in the case of the tenant as in that of the owner, because the former usually pays an average rent of less than 5 per cent on the value of the real estate, and consequently his operator's labor income is higher than the farm labor incomes calculated by the deduction of 5 per cent for all capital employed in farming. On the basis of operators' labor incomes, as distinguished from farm labor incomes, only 3 per cent of the tenants in the Tama district made minus labor incomes in 1918, although 11 per cent failed to earn the estimated value of operators' labor and superintendence. On the other hand, in the Warren district, where the per cent of rent to land values in 1918 averaged somewhat higher than 5 per cent, 9 per cent of the tenants failed to make plus operators' labor incomes in 1918, while 59 per cent failed to earn the value of the farmer's labor and superintendence.

THE FARMER'S POWER OF ACCUMULATION AS INDICATED BY DATA ON NET WORTH.

In obtaining data concerning the income of Iowa farmers in 1918 information also was obtained with regard to the net worth of the farmers at the end of the fiscal year 1918; that is, on March 1, 1919. These facts are shown in Table XX.

The table shows the average net worth of farmers who own their farms in the Tama district to be the very substantial amount of

\$65,464, while it is \$30,915 in the Warren district. The owners additional in both districts have average net worth somewhat less than that of owners.

TABLE XX.—*Net worth, March 1, 1919, of farmers classified by ages and tenures.*

Tenure and age group.	Tama district.		Warren district.	
	Number of farms.	Net worth.	Number of farms.	Net worth.
I. Owners:				
Under 31.....	7	\$57,216	5	\$10,775
31 and under 41.....	30	65,153	19	31,020
41 and under 51.....	28	57,060	20	34,287
51 and over.....	21	79,864	40	31,695
All ages.....	86	65,464	84	30,915
II. Owners additional:				
Under 31.....	3	28,202	4	19,040
31 and under 41.....	7	42,541	9	20,376
41 and under 51.....	14	50,653	11	27,509
51 and over.....	4	45,990	19	27,593
All ages.....	28	45,269	43	25,266
III. Tenants:				
Under 31.....	28	6,639	15	4,502
31 and under 41.....	40	9,258	18	3,138
41 and under 51.....	21	13,138	15	2,816
51 and over.....	8	11,818	8	3,238
All ages.....	97	9,552	56	3,415

It should not be inferred that the comparatively large sums represented by the net worth of owners and owners additional have been accumulated wholly by farming. They are largely the results of increase in value of land acquired by purchase, by marriage, or by inheritance at an earlier time, supplemented to some extent by other wealth acquired by marriage or inheritance. In a few cases, perhaps, net worth is the result of unusual agricultural efficiency combined with thrift or fortunate investments outside of farming. What may be acquired by actual farming, as distinguished from increase of land values, is suggested by the figures showing net worth of tenants of various ages. The average net worth of tenants of all ages is \$9,552 in the Tama district and \$3,415 in the Warren district.

It might be supposed that the comparatively small average net worth of tenants is attributable to the fact that the more successful tenants have risen to the position of owners or owners additional, leaving only the less successful in the tenant class. While there is undoubtedly some truth in this supposition, yet it is not likely that it applies with much force to the groups of tenants below the age of 41. Comparatively a small proportion of Iowa tenants become owners before the age of 41. In fact, only about one-third of the owners have acquired ownership before the age of 41, and undoubtedly these have received substantial assistance from wealth acquired by inheritance, marriage, or gift, either of the farm itself or of the means by which it is purchased.

The general truth of the proposition that owners of Iowa farms have acquired present net worth largely by increase in land values may be roughly tested by interpreting available facts with regard to the average period of ownership and the average increase in land values for the period. The essential facts are shown in Table XXI.

TABLE XXI.—*Average present age of owners who operate their farms, average years an owner, average years of ownership of present farm, Tama district.*

Age groups.	Average present age.	Average years an owner.	Average years owner of present farm.
Under 31 years.....	28.5	3.8	3.4
31 and under 41.....	36.5	8.9	7.4
41 and under 51.....	46.1	12.1	10.5
51 and over.....	56.2	21.2	16.1
All farmers.....	44.0	12.7	10.5

The average period of ownership is 12.7 years. Assuming that the acreage owned throughout the period has been the same as the present acreage owned, the average addition to net worth for the period of ownership from increase of land value alone may be estimated at over \$60,000. As shown in Table XX, the average net worth on March 1, 1919, was \$65,464. However, of the total increase a little more than \$18,000 occurred from March, 1919, to August, 1919, making a corresponding addition to net worth. Accordingly, it appears that of a total net worth of about \$84,000, approximately \$60,000 is due to increase of land value.

It may be said, of course, that it is incorrect to assume that the same acreage has been owned throughout the period of ownership, and there can be no doubt that this introduces a factor of uncertainty into the estimate, especially in view of the fact that there has been a tendency for the average size of Iowa farms to increase. However, the fact should be noted that there is no discernible tendency for the average size of the farm to increase with the age of ownership. Indeed, there is a decline during the first three age-groups, with a slight increase in the last. Moreover, the assumption takes no account of the increment of value obtained from parcels of land acquired and resold, nor of the increment from additional farms owned by the individual farmer. Consequently it is not improbable that at least \$60,000 of the total net worth of farm owners in the Tama district may be accounted for by increased land values.

Moreover, the farmers have attained their present net worth in part by inheritance, gift, and marriage. The double influence of inheritance, marriage, and gift on the one hand and of retirement from farming on the other is shown by the small difference between the

average net worth of the youngest and oldest age-groups. The former group is largely recruited by young men who have obtained their wealth by inheritance, marriage, or gift. This is indicated by the figures on inheritance, the average being much larger for the youngest age-group than for the older age-groups. On the other hand, the eldest age-group is constantly being depleted by retirement from farming.

It should be noted that the amount of net worth not accounted for by the above explanations was not all acquired during the 12 years of ownership, for many owners had acquired considerable net worth as tenants before becoming owners.

Finally, there can be little question but that a considerable part of the present average net worth is due not only to increase of land values but also to accumulations made possible by the unusually favorable conditions of the war period affecting farm incomes.

It is difficult to see how tenants with an average net worth of \$9,552 can hope to acquire the ownership of farms which together with necessary operating capital represent an average investment per farm of \$86,957 in August, 1919. The process of climbing to the top of the agricultural ladder may have been easier in 1913 when the total investment averaged \$46,029, or even in 1918 when it was \$60,663, than it is likely to be in the future. The process of acquiring ownership by borrowing a large part of the purchase price of a farm must be especially difficult when under the favorable conditions of 1918 owners of farms made an average net return which would yield only 3.5 per cent on the average value of the farm investment in August, 1919. Moreover, the relative financial undesirability of assuming ownership under present conditions is emphasized by the fact that tenants were able to earn 32 per cent on their invested capital besides earning the estimated value of their labor and superintendence. (See Table XVI.)

In the Warren district conditions are in some respects more favorable to the passage from tenancy to ownership than in the Tama district. Not only has the average value of land been lower, but also it has been capitalized at a higher rate of interest, which is shown by the fact that the average net return of landlords, even in the unfavorable year of 1918, was 5.33 per cent, as compared with 2.43 per cent in the Tama district. (Table XIV.) However, the annual labor income of farmers in this district from which savings may be derived was very much lower than in the Tama district, not only in the unfavorable season of 1918, but also in 1915. This general fact is reflected in the lower average net worth of tenants in the Warren district, which is less than half that of the Tama district.

The difficulties of acquiring ownership of this high-priced land should not be confused with the question of the possibility of accumu-

lation of wealth by tenant farmers. The average labor income of tenants in the Tama district was \$3,053 in 1918; in addition to this, the tenant was allowed \$354 for his working capital, as well as the value of the labor performed on the farm by members of the family and the value of living obtained from the farm. Certainly the favorable conditions of the war period made possible considerable accumulation by tenants. In 1913, however, the average labor income of tenants was but \$1,315 in the same district.

SUMMARY OF CAUSES AND PROBABLE EFFECTS OF THE "BOOM."

CAUSES.

The great attention attracted by the recent unusually rapid increase in the values of farm lands and in the activity in buying and selling farm land has resulted in the advancement of numerous theories in explanation of these phenomena. It would be difficult to suggest probable causes which have not already been mentioned in popular discussion. However, it may be desirable to indicate the relative importance of the several causes mentioned, to test them so far as possible by the known facts, and to suggest their mutual interrelation.

From the standpoint of causes it is desirable to distinguish to some extent the increase in activity in buying and selling from the increase in values. An increase in value, if not too abnormal, may occur without being accompanied by any considerable increase in buying and selling activity. In fact, a steady increase in value was taking place prior to the beginning of the "boom" of 1919. However, it is clear that the increase in value and the increase in sales activity were due in part to identical causes during the spring and summer of 1919, and, moreover, the increase in values and increase in sales activity mutually influenced one another—that is, the increase in value tended to stimulate activity in buying and selling, while this activity in turn reacted upon values.

Foremost as a cause is the fact that farm income, as a result largely of war prices for farm products, increased for a time more rapidly than land values. This fact is clearly established by the analysis of farm incomes. (See above, p. 21.)

This truth was sometimes expressed in popular discussion by the statement that there was "little or no increase in land values during the war period, and an increase was, therefore, about due." This is, of course, but a half truth, for it has been shown that there was a probable average increase of approximately \$15 per acre during the period from March, 1918, to March, 1919, if this may be taken to comprise a greater part of the war period. If the latter term is employed to coincide with the entire duration of the European war—from 1914 to the beginning of 1919—there was undoubtedly a much larger increase.

If the primary cause for the "boom" was the marked increase in the net income of farms, it is in point to consider what conditions were responsible for this increase.

It is sometimes asserted that it was due to the fact that the dollar had fallen to less than half its purchasing power before the European war. Sometimes this cause is invoked as the immediate cause of the rise in the value of farm land, on the assumption that if the dollar is worth only half as much as formerly it should require twice as many dollars to purchase the same farm as formerly. Sometimes the more indirect explanation is offered, that the fall in the value of the dollar has resulted in a great rise of the prices of farm products—specifically \$23 hogs, \$2 corn, etc.

It should be clear, however, that people buy farm land primarily because of the desire for the net earnings to be derived from ownership. Net earnings attributable to the land are not only dependent on the prices of products, but also on the expenses of production. If prices of products are doubled and the expenses are also doubled, the net earnings attributable to the land, expressed in dollars, also will be doubled. If expenses increase in greater proportion than prices of products, net income will increase in less proportion than the prices of products. Conversely, if the expenses of production increase in less proportion than the prices of products net earnings will increase in greater proportion than the latter.

As a matter of fact, the latter tendency seems to have prevailed during the period 1914 to 1918, inclusive. The December price of corn for Iowa increased 112 per cent from 1914 to 1918, while the price of oats increased 62 per cent. The January price of hogs increased 150 per cent from 1915 to 1919.¹

On the other hand, the wages of farm labor without board increased 112 per cent from 1914 to 1918, inclusive, and the average prices of 17 important commodities used by farmers in production increased 85 per cent.² Moreover, during this period farmers used many kinds of equipment bought at the earlier prices of the prewar period, such as machinery, work horses, harness, etc. It should be noted that the rise in prices of farm products reached its peak in August, 1919, a time when the "boom" was at its height.

In short, expenses did not increase as rapidly as the prices of products. Likewise, land values lagged behind, for some time was required before the increase in net earnings attributable to the land was fully reflected in the demand for land. There is a widespread belief in Iowa that the demand for land was even retarded during the war

¹ The January prices of hogs for 1915 and 1919 are taken because they are the nearest comparable figures to those for December of the preceding year in each case. The difference is only 1 month instead of 11 months, as would have been the case in comparing December and January of identical years.

² Including various kinds of farm machinery, fertilizers, harness, lumber, fencing, and other items. These figures as well as those for Iowa prices of farm products are from the "Monthly Crop Reporter."

because farmers who would otherwise have purchased farms for their sons postponed these purchases until the boys should return from the army, while many farmers were investing in Liberty Bonds instead of in land. With the close of the war and return of the soldiers this source of demand for land again became effective. It is difficult to prove this theory, but it seems probable that it may account in part for the "boom," although undoubtedly a subsidiary cause.

The large increase in the net earnings of farmers was responsible for the "boom" in still another way. It increased the investable funds in the hands of farmers. This condition was also rendered still more favorable by the easy market for credit which prevailed in 1919. Both conditions were reflected in the financial status of State and savings banks and trust companies. A statement of the condition of 371 State banks, 926 savings banks, and 23 trust companies in the State of Iowa, published in the press under date of July 22, showed that bank deposits had increased more than \$100,000,000 during the year, or about 17 per cent, while loans and discounts had increased less than \$40,000,000, a little over 8 per cent.

By easy market for credit is not meant easy terms of credit. We have no grounds for believing that during the period of the "boom" there was a strong tendency to lower the standards of security ordinarily required in Iowa for farm purchases financed by credit. What is meant is that loanable funds both for mortgage and for personal credit were abundant. Not only was this true of bank credit, but it was especially true of credit furnished by the sellers of farms. Large numbers of farmers who had prospered during the war desired to retire, and many of them were glad to avoid the responsibility of, and risk involved in, renting land, by converting their equities so far as possible into farm mortgages.

Such were the important conditions which formed the basis of increased activity in buying and selling land in the spring and summer of 1919, and the accompanying increase of land values.

This movement, however, was cumulative, increasing of its own momentum. As soon as it became apparent that land values were rising the speculative interest developed. Many people who otherwise would not have been interested in the land market bought for the purpose of selling again within a short time. The motive was not for investment and had little reference to the earning power of the land except so far as this might form a basis for judging the probability of further increase of value. This class of buyers increased the volume of demand for farm land. Moreover, since most of this class also desired to sell again as soon as a substantial speculative profit could be realized, the volume of supply was considerably increased. From one-fourth to one-third of purchases and sales were made primarily for speculative motives. There were many persons,

including large numbers of farmers who had prospered during the war, who had been intending to purchase farm land, but who for one reason or another had postponed action. Fearing that their desires might not be realized before values rose too high, these people hastened to buy. On the other hand, there were shrewd landowners who had long held land for an increase of value who believed it a good time to take their speculative profits by selling. There were many farmers who found themselves able to retire on a comfortable competence by selling their lands at the increased level of values.

The professional land dealers did their part to increase the activity and intensify the excitement. They rode from farm to farm persuading farmers to sell and encouraging others to buy, sometimes stimulating the movement by fictitious sales. As already noted, a large proportion of high-grade farms were sold in the early months of the year, and the high prices received were widely advertised. Inveterate optimists and professional "boosters" found their optimism confirmed by the fact that Iowa farm land had "never gone back." Stories of sales at unheard-of prices and of large profits made over night were prevailing topics of conversation and occupied much space in local newspapers. The press made much of the high prices of farm products and helped to create the widespread impression that high prices of products would continue for a long time.

Thus there sprang into being among many people a supreme confidence that prices of farm products would remain at the present high levels and that land would continue to increase until \$500 and \$600 per acre would be prevailing values of Iowa farms. Consequently the great activity in buying and selling land reacted on land values, pushing them up more rapidly than they would have increased otherwise, while the rising values stimulated increased activity in buying and selling.

IMMEDIATE CONSEQUENCES.

One of the most important immediate consequences demonstrated by this study is that the increased activity in buying and selling farm land resulted in increasing the proportion of farm owners operating their farms while correspondingly reducing the number of farms owned by urban dwellers and operated by tenants. While a considerable number of farm operators seized the opportunity to sell out and retire, this reduction in the number of farms operated by owners was more than compensated by the number of farms purchased by tenants or by owner operators who increased their holdings. It is probable, however, that this tendency will not affect to a marked extent the percentage of tenant farmers, because probably not more than 10 per cent of the farms of the State changed ownership during the "boom." On the other hand, this small percentage of change in

ownership may be considered fortunate in that a comparatively small proportion of the present farmers of Iowa have assumed the heavy financial handicap involved in the purchase at the excessively high level of values resulting from the "boom." Probably not more than 5 per cent of the farms of Iowa were acquired by actual farmers at boom "prices." The remaining 95 per cent of the farmers have marked up the prices of their farms, and in case of necessity can mark them down again.

The "boom" was a process of rapid recapitalization of Iowa farm lands on the basis of the high prices of farm products and relatively high farm earnings of the war period. The process brought about an average increase of about \$66 an acre, amounting to an increase of about \$200,000,000 for farms actually sold, and, if imputed to all the farms of the State, resulting in a total increase of more than \$2,000,000,000. Active farmers assumed a larger proportion of the recapitalized values than they had held of former values. Urban owners took advantage of the process of recapitalization to realize the increments of land values that had accrued during the period of ownership, with the result that these urban dwellers received nearly half of all the increment of value in the case of farms owned by the sellers before the beginning of the "boom" and more than two-thirds of the increment derived from resales of farms purchased during the period of the "boom."

The process of recapitalization and redistribution of ownership occurred without any serious tendency toward "shoestring" speculation such as sometimes accompanies a land "boom." There were unquestionably some instances of this character, but they were exceptional. The great majority of buyers were people of substantial means, and the terms of sale were not much less conservative than those sanctioned by prevailing custom in the region. Moreover, the practice of reselling contracts of sale was not as extensive as was generally believed. Consequently the March settlement following the "boom" occurred without a serious credit stringency. Some uncertainty and resulting litigation may grow out of the complications from resales, but this is of minor consequence.

Some temporary inconvenience and delay in the making of tenant contracts also resulted from the "boom" due to the uncertainties of ownership, but this was also a minor consequence because of the fact that not more than 10 per cent of the farms were sold and not more than one-fourth of these were resold.

ULTIMATE CONSEQUENCES.

The immediate consequences of the "boom" of 1919 are of relatively minor significance as compared with the ultimate consequences. The latter grow out of the relation of farm values to farm incomes

and the probable effect of this relationship on the possibility of farmers acquiring ownership. For the relative increase in farms operated by owners is an immediate, but not necessarily an ultimate, result of the "boom" and the accompanying increase in land values.

By every method of analysis employed it is shown that relative to farm earnings, even under the favorable conditions of 1918, the increase of land values was excessive. In the Tama district, where both good prices and excellent crops combined to produce unusually high farm earnings, farm income of all farms increased 65 per cent from 1913 to 1918, while land values increased 82 per cent to August, 1919. As a result of high prices for farm products farm labor incomes were relatively higher in 1918 than in 1913, even if allowance be made for the change in the purchasing power of the dollar, whether the calculation be made by charging 5 per cent or $5\frac{1}{2}$ per cent for use of the capital. However, when farm labor incomes are calculated on the basis of 1919 land values, a marked change occurs. When capital is charged 5 per cent, the payment for the farmer's labor, enterprise, and risk declines from \$306 in 1913 to \$222 in 1919. On the basis of a $5\frac{1}{2}$ per cent charge for capital, the average farm labor income for 1919 in the Tama district is \$213 less than nothing. When allowance is made for the decline in purchasing power of the dollar, the decline in labor incomes is further intensified.

Thus it appears that high prices of the war period increased farm labor incomes in considerably greater proportion than the decline in the purchasing power of the dollar, but the advance in land values more than absorbed all the gain, forcing labor incomes, even measured in dollars, far below what they were in 1913. Furthermore, the result of increased land values is to increase the percentage of farmers making minus labor incomes from 15.6 on the basis of land values in 1918 to 42.2 on the basis of land values in August, 1919.

If these are the results under the favorable conditions of good crops and high prices, what may be anticipated when the crops are poor and prices lower? The effect of poor crops is shown by the statistics of income for the Warren district, but the effect of a general fall in the level of prices will be far more serious, for it will not apply merely to an occasional year:

While the comparison of labor incomes for the several periods serves to show that land values increased more rapidly than earning power, some may question the practice of deducting 5 per cent for the use of capital, including land value.

For some years there has been a tendency, not only in Iowa but in certain other farming regions of the United States, to capitalize land at a lower rate than 5 per cent—that is, to value it so high that it will not yield, over a period of years either to owner operator or to landlord, as much as 5 per cent on the value.

This tendency is attributable to several causes. The most important is the fact that constantly increasing values of land have yielded an increment which may be counted as a substantial addition to the income derived annually from the rent or use of the land. It is obvious, however, that whether this fact may be considered a justification for the present high land values depends on whether the increase may be expected to continue. The reply of many people in Iowa is that land always has increased in value; therefore it will continue to increase.

Another reason for the low rate at which farm land is capitalized is the fact that the farm is not only the source of money income, but also yields satisfaction as a home. Therefore a part of the high land values represents allowance for home advantages, including residence and other conveniences, good roads, schools, and other social benefits.

A most important reason, however, is the tendency for farmers to invest in land with little consideration for the possibilities of other lines of investment. This tendency may be explained by ignorance of other methods of investment, by the belief that investments in farm land are peculiarly safe, and by the pride of ownership, or the mere blind passion for ownership which causes many farmers—especially peasant immigrants—to accept a low standard of living in order to acquire land.

As a result of these conditions the average cash rental of farm land in 49 Iowa counties in 1918 was 2.71 per cent of land values, March 1, 1918, and 2.35 per cent of land values, March 1, 1919. The percentage of land values for August, 1919, would be still less. In the Tama district cash rentals were 2.15 per cent of land values in 1913, 1.90 per cent in 1918, and 1.30 per cent of the land values of August, 1919. It should be noted, however, that owners operating their farms are able to earn a slightly larger percentage of return than would be derived from renting them to others for cash rent. Thus, the per cent of average return to owners from operation in the Tama district was 3.98 in 1913, 4.99 in 1918, and 3.5 on the basis of land values in August, 1919.

If, on account of the various motives mentioned above, farm owners are willing to pay prices for land which will make it necessary to take considerably less than 5 per cent for the use of the land, shall we consider the value of farm land abnormal, and the condition itself one to be deplored?

The question may first be considered from the standpoint of farm owners, however they may have attained that status. If the owner is free of debt, the rent of the land combined with the income assignable to the labor of the farmer and his family, together with interest on operating capital, may enable him to live in considerable comfort.

Thus, the average farm income in 1918 of owners in the Tama district was \$4,272, and in the Warren district, \$1,997, besides living obtained from the farm and such income as may be attributed to the labor of the farm family.

However, even supposing an owner to be clear of debt, he would obtain a larger income by selling his farm property and becoming a tenant, investing the surplus wealth not needed for operating capital in sound bonds or mortgages. Thus, the owner of the average farm capital of \$88,404 could invest \$7,081 as farm operating capital, and under the conditions of 1918 could earn a labor income of \$3,053 after paying rent, besides 5 per cent interest on the \$7,081 invested amounting to \$354. The remaining capital, \$81,323, invested at 5 per cent would yield \$4,066.15. Thus the total income obtained by this method would be \$7,473.15 in addition to living obtained from the farm and such income as was credited to the labor of the farm family.

The above analysis assumes that the farmer owns outright the total amount of the farm capitalization. If half the capital value as of August, 1919, were borrowed at $5\frac{1}{2}$ per cent, only \$1,841 of the farm income in the Tama district would remain, and this under the favorable conditions with respect to crops and prices in 1918. In the Warren district such an owner would have had only \$784.80 left, after paying his interest, from which to live and reduce the principal of the loan. If the debt had amounted to three-fourths the value of the investment—and one-fourth of the sales involved at least this per cent of indebtedness—the remaining income after paying interest would have been \$626 in the Tama district and \$179 in the Warren district.

By inference from the above analysis we may derive the relation of the present high level of land values to the status of a tenant. It was shown clearly that even if a farmer has sufficient wealth to purchase a farm outright, he can obtain a larger total income by remaining a tenant and investing in bonds or mortgages the remainder of his wealth, above the amount needed for operating capital. Hence, there is a financial premium on remaining a tenant rather than becoming an owner.

On the other hand, even if the tenant desires to become an owner, the financial handicap of paying 5 per cent or more on borrowed capital to purchase land which will yield 3 per cent or less on the investment demands serious consideration, with special attention to the possibility that prices of farm products may decline. Finally, it is obvious, since the average net worth of the tenant is so small as compared with the total value of the farm investment required to operate as an owner—about 11 per cent—that at least 89 per cent of the total investment must be borrowed by the tenant who buys

under these conditions. Heretofore, these obstacles have not been so great, for the increase of land values alone has been sufficiently large to amortize a large part of the indebtedness. Thus, a tenant who bought land in the Tama district at the average value of \$192 an acre in 1913 could have borrowed 85 per cent of the purchase price and sold the farm for enough to repay the debt out of the increase in value during the six years. Unless farm land may be expected to continue to advance steadily in the future, this important means of acquiring wealth sufficient to repay indebtedness incurred for purchase will not be available.

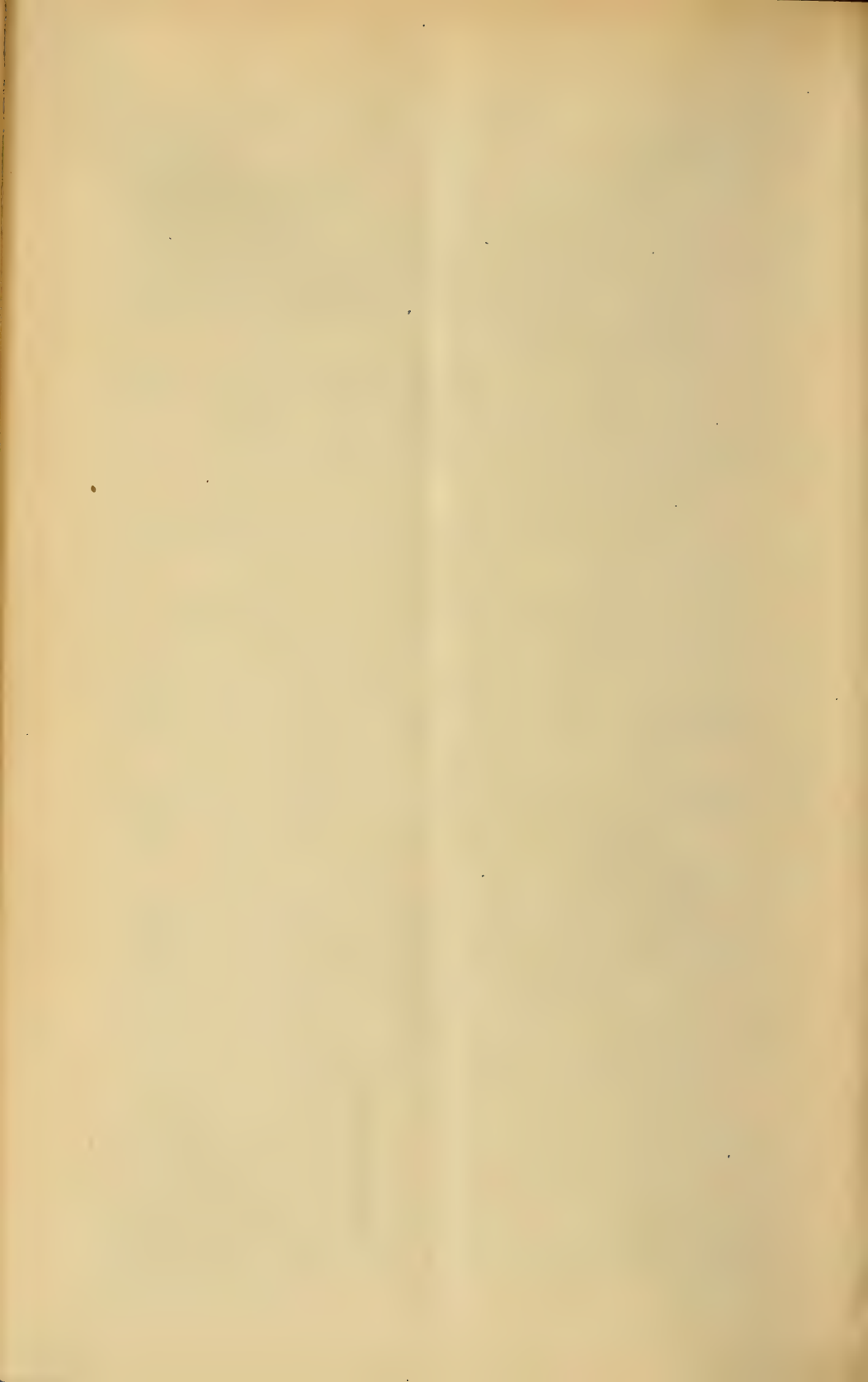
It appears, therefore, that in view of the financial undesirability, as well as the almost insuperable difficulty, of tenants acquiring ownership under present conditions, comparatively few tenants may be expected to change their present status, unless there occur a marked change in conditions.

The question whether the present level of land values is to be considered abnormal and to be deplored should finally be tested not only by the interest of the individual owner or tenant, but also by the general public interest.

Is it to the public interest that farmers must pay so much to acquire the ownership of land that they can earn very much less on their investment than if they invested in other lines of business? Is it to the public interest that the making of a return equal to the market value of the farmer's labor is so precarious, on account of the high capital charges of the business, that from 65 to 85 per cent of the farmers, in a time when conditions were unusually favorable to agriculture, failed to earn that amount? Finally, is it desirable that land values should be so high that it is financially both undesirable and impossible for a large percentage of tenants to acquire the ownership of a farm?

The reader may answer these questions according to his own point of view. From the point of view of the writers the questions themselves suggest the unwholesomeness of the tendency toward the overcapitalization of the earnings of farm lands—a tendency prevailing not only in Iowa, but in other agricultural regions before the recent "boom," but carried to a greater extreme in the rapid recapitalization of land values that has been described in this study.







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L. O. HOWARD, Chief

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COTTON BOLL WEEVIL CONTROL BY THE USE OF POISON.¹

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PRINCIPLES GOVERNING POISONING OPERATION.

IT SHOULD BE UNDERSTOOD that in poisoning for boll-weevil control extermination is not attempted or secured. The result aimed at is a sufficient reduction of the weevil infestation to permit maturing a full crop of cotton. This is brought about by tak-

¹ The investigations upon which this bulletin is based were in a sense the outgrowth of the work of Mr. Wilmon Newell, who published, together with Mr. G. D. Smith, in

ing advantage of a combination of factors. In the first place, the cotton plant has a peculiar habit of putting on much more fruit than it is able to mature. About 60 per cent of the squares which appear on the cotton plant fail to reach maturity as bolls, and are shed at some time during their development. This does not mean, however, that the cotton plant is shedding 60 per cent of its fruit throughout the season. This shedding is comparatively slight early in the season and increases rapidly as the plants develop until it reaches the point where all the new fruit which appears is shed. It has been found that up to a certain point the fruit shedding due to boll-weevil attack merely takes the place of this perfectly normal shedding which would be encountered even if the weevils were absent.

The present system of weevil poisoning is intended merely to keep the weevils controlled to such a degree that they will not be able to do more than offset the normal shedding of the cotton plants. This means, generally speaking, that the weevils are permitted to multiply unmolested until they have become sufficiently abundant to puncture more forms than would shed normally. Poisoning is then started and every effort is directed toward holding the infestation below this point of danger until the plants have had sufficient time to develop beyond weevil injury as many bolls as they will be able to mature. Then poisoning is stopped and the weevils are allowed to resume multiplication. Experience has shown that remarkably large increases in yield frequently result from a comparatively slight degree of control for a short time during this critical period. It has also been very definitely determined, however, that this effect is cumulative and can only be secured by starting the applications at the right time and repeating them at the correct time interval. This is the reason the writers urge everyone contemplating weevil poisoning to decide upon conducting the operation as thoroughly as recommended or not to attempt it at all.

Circular 33 of the Louisiana State Crop Pest Commission, an account of experiments in controlling the boll weevil by the application of powdered arsenate of lead which were conducted in Louisiana during 1908 and 1909.

The studies of the U. S. Department of Agriculture on the subject of cotton boll weevil poisoning were first described in Department Bulletin 731, July, 1918. The present bulletin gives the results of investigations carried on since that time. It is to be followed by a detailed bulletin giving descriptions of the various tests and studies which serve as a basis for the recommendations made. The latter will also include a discussion of the contributions to the subject which have been made by various investigators for many years. The work has been conducted under the general direction of Dr. W. D. Hunter. The development of dusting machinery has been under the direction of Elmer Johnson, of the Bureau of Public Roads. The following have contributed to field and laboratory studies: F. F. Bondy, H. W. Lec, T. F. McGehee, R. W. Moreland, L. Z. Naylor, M. C. Rodgers, E. S. Tucker, W. B. Williams, and M. T. Young. The practical field tests have been rendered possible only by the hearty cooperation of the following: Prof. J. W. Fox, general manager, Delta & Pine Land Co. of Mississippi, Scott, Miss.; Mr. Alex. Y. Scott, general manager, Charles Scott's Delta Plantations, Rosedale, Miss.; and Mr. George S. Yerger, general manager, Maxwell-Yerger Planting Co., Mound, La.

KIND OF POISON TO USE.

In the various studies which have been conducted by the writers, nearly every known type of arsenical has been tested, but the first generally successful results were secured from the use of an improved type of arsenate of lead. This was soon replaced by calcium arsenate, and this chemical remains the best which has been found for this purpose so far. Tests were conducted with both liquid and dry applications, and it was found that with the liquid spray a slight degree of control was secured, but not nearly enough to make the operation profitable.

POISON SPECIFICATIONS REQUIRED.

When calcium arsenate was first tested it was found that the material as then prepared was not safe for use on cotton plants, owing to the injury caused by burning of the foliage. This was due to the excessive amount of water-soluble arsenic present. It was found that it was possible to make calcium arsenate without this high percentage of soluble arsenic, and the type which is now recommended for this work is absolutely safe for use on plants. Not all calcium arsenate, however, is of this safe type. Anyone attempting this work should purchase the calcium arsenate on specifications describing its composition. The specifications advised are as follows:

Not less than 40 per cent arsenic pentoxid. Not more than 0.75 per cent water-soluble arsenic pentoxid. Density not less than 80 or more than 100 cubic inches per pound.

Calcium arsenate was almost unknown as an insecticide when these experiments were inaugurated, and its production had been attempted by only a few manufacturers. Recently, however, almost all insecticide manufacturers have undertaken its production. While its manufacture is comparatively simple, some experience is required to produce a thoroughly satisfactory material. Undoubtedly this difficulty will decrease rapidly as the manufacturers gain more experience in the production of calcium arsenate and the quality of the material becomes standardized, but for the present it is still advisable to make purchases only on the specifications recommended. If the total arsenic content is too low, the material is not sufficiently poisonous to control the weevil. If the proportion of water-soluble arsenic is too high, plant injury will be the result. Some lots of calcium arsenate have been found which killed the cotton plants within a few hours after application. It is also important to watch the density of the material very closely. If it is too heavy and runs much less than 80 cubic inches to the pound, it is not suitable for use in dry powdered form and will not produce the proper type of dust

cloud to cover the cotton plants thoroughly. Likewise, if the material is too light and runs much over 100 cubic inches per pound, it is blown away from the plants too rapidly by any light air currents.

SEND SAMPLES OF CALCIUM ARSENATE FOR ANALYSIS.

The best way to make sure of having the proper grade of calcium arsenate is to send a sample to the Delta Laboratory at Tallulah, La., for free analysis. This analytical service was started by the United States Department of Agriculture last season and if possible will be continued until the quality of calcium arsenate on the market becomes more uniform. Every cotton planter who purchases calcium arsenate for this work is invited to send in samples and he will be given an immediate report as to whether or not the material is satisfactory for use in cotton dusting. For this purpose it is advisable to take at least two or three samples from as many different packages. Probably the best plan is to sample 1 package in every 10 purchased. Half-pound samples should be taken from each and packed separately. The complete record of each sample should be packed with that sample, giving its full history, including name of manufacturer, when purchased, size and type of package, condition of material, analysis claimed by manufacturer, etc.

USE OF MIXTURES NOT RECOMMENDED.

The only chemical now recommended for boll-weevil poisoning consists of calcium arsenate which conforms to the specifications described. Attempts have been made to utilize various mixtures of arsenicals or dilutions of calcium arsenate. It is quite possible that some of these may prove satisfactory in the future, but with our present information it is advisable to adhere strictly to the use of calcium arsenate without the addition of any diluent whatever.

SUPPLY OF CALCIUM ARSENATE AND DUSTING MACHINERY AVAILABLE.

Prior to 1919 the production of calcium arsenate was so limited that it was difficult to secure a sufficient amount to conduct the experiments desired in this work. During 1919, however, interest in its production was stimulated to the point where probably 3,000,000 pounds were sold for cotton-dusting work. It appears that a fairly ample supply of calcium arsenate will be available for 1920. This is especially true in view of the probable shortage of dusting machinery. It has been found that successful results can not be secured unless special types of dusting machinery are utilized. These machines must be prepared for this particular purpose and their development has been considerably slower than that of the poison. At the present time the supply of machinery available is hardly sufficient to serve for the proper application of the poison already sold by the various manufacturers.

KEEPING QUALITIES OF CALCIUM ARSENATE.

Questions frequently are received as to whether or not calcium arsenate will deteriorate during long periods of storage. In some cases farmers purchased more than they could use during the past season and desired to hold over their surplus stock for use during the coming year. This is perfectly safe, as a properly made calcium arsenate should not deteriorate if stored in a reasonably dry place. Some lots have been kept at the Delta Laboratory for four years under normal storage conditions without the slightest deterioration. Moisture, however, even when it does not induce chemical deterioration, will cause calcium arsenate to cake so badly that it can not be utilized in the dusting machines.

EFFECT OF THE POISON ON MAN AND ANIMALS.

Questions are frequently asked regarding the effect of calcium arsenate on laborers and mules engaged in the poisoning operations. It is not nearly as dangerous as Paris green, as it does not have the caustic action characteristic of the latter. There is, however, a certain amount of danger attendant upon the use of any arsenical compound and reasonable precautions should be taken to protect the men and animals associated with it. Inhaling the dust should be avoided as far as possible. The most important precaution is that of personal cleanliness when using the material. The operators should be forced to bathe as soon as they complete the dusting work, and they should not be permitted to eat anything without at least washing their hands and face thoroughly. No injury to work stock has ever been experienced during operations, but it is safest to keep ordinary wire muzzles on all such animals in the poisoned fields.

The question of fall grazing of poisoned cotton fields is frequently raised. As a rule the last application of poison is made at least a month, and usually two or three months, before the cotton crop is harvested and the animals allowed to graze on the cotton fields. Even if no rains have occurred to wash the poison from the plants during this period, the amount of leaf shed has been so great that the foliage of the plant has probably been renewed several times and the plants utilized for grazing purposes are largely, if not entirely, new growth.

With regard to the danger to man involved in the use of calcium arsenate in the form of a dust cloud, it should be understood that arsenic may be taken into the body in three ways—by the mouth, by breathing, and by absorption through the skin. Ingestion or swallowing is the only manner which usually receives serious consideration, but in all probability it is the least important of the

three and can be avoided very easily by careful washing of the hands and face before eating or drinking.

Inhalation is a danger which is constantly present and is difficult to avoid except by the use of dust masks or some type of filtering arrangement which removes the dust from the air entering the mouth and nostrils.

Absorption undoubtedly is a very important means of taking arsenic into the human body. Even if extreme precautions are taken during dusting operations to avoid excessive direct contact with the poison supply, there is still a very considerable amount of poison dust settling all over the body from the air. This also has a decided tendency to adhere to the skin and "shed" water unless a strong lather is utilized, so a hasty rinsing in clear water should not be considered as a satisfactory means of removing the poison.

The danger of poisoning, although slight, should be considered. In the work conducted under the direction of the writers large quantities of calcium arsenate have been used by all sorts of laborers and generally with extreme carelessness. In spite of this, however, very few definite symptoms of even the slightest arsenical poisoning have been observed in connection with the field operations, and these few undoubtedly would have been avoided if proper precautions had been taken. Anyone using dry powdered calcium arsenate need not fear poisoning if he is reasonably cautious, but if any unexplained illness should develop during its use the possibility of poisoning should be borne in mind and a physician consulted. The preliminary symptoms of arsenical poisoning differ widely, but generally involve an intestinal and digestive disorder and are usually accompanied by some form of skin eruption.

An additional indirect danger to live stock should be considered. The cloud of poison frequently has a tendency to drift considerable distances. Conditions may be such that a dangerous amount of poison will drift into a neighboring pasture and injure some of the stock feeding on the grass. Stock should certainly not be allowed to graze on headlands and turnrows in fields which are being poisoned. The same applies to chickens, turkeys, and other fowls. The only fatalities the writers have observed in the course of poisoning work have been in the case of chickens and turkeys running in poisoned fields and picking in the debris covered with a heavy dosage of poison, where the machine had stopped and covered the ground rather thoroughly.

PLANT INJURY BY CALCIUM ARSENATE.

It is well to explain briefly the usual nature of arsenical injury to cotton plants, as there is a tendency on the part of inexperienced

operators to blame the poison for any form of plant disease. Plant injury by soluble arsenic ordinarily is termed "burning," and this word probably describes the appearance of the condition better than any other. The plants look very much as if they had been burned or scalded by some hot application, especially in cases of severe injury. The leaves and terminals droop and the young and more tender shoots wilt badly. This is followed very shortly by the death and drying of the most seriously injured tissue, causing lighter colored spots of dead tissue to appear over the leaves. In cases of mild injury this frequently involves only a sort of "shot-hole" effect over the leaves, but when the injury is severe the entire leaf is killed and falls from the plant in a short time. In still more severe cases the entire plant may die soon after the application.

One fact which should be borne in mind is that plant injury by soluble arsenic is generally very erratic and depends to a great extent upon the weather conditions prevailing at the time of and directly following the application. It will be noted in the specifications that a maximum limit of 0.75 per cent of water-soluble arsenic oxid is recommended. This does not mean that all material containing more than this amount of water-soluble arsenic will be injurious to the plants at every application. In reality, applications of calcium arsenate containing as high as 3 or 4 per cent of water-soluble arsenic frequently will not burn the plants, but it has been found from a large number of tests that any material running over the maximum limit established in these specifications will burn the plants seriously *when certain weather conditions are experienced*. The most dangerous calcium arsenates are those averaging about 2 or 3 per cent in water-soluble arsenic, as it is possible to make two or three applications of these before any plant injury is experienced.

The most dangerous conditions possible for plant burning are found during showery days when there are alternate showers and bright sunshine. On such a day the plants are moist and the atmospheric conditions ideal for making a satisfactory application of poison, but it has been found that if the water-soluble arsenic content of the poison used is the least too high it will produce very severe injury.

Another point which should be noted is that very serious loss from plant burning may result from a degree of injury which appears very slight at first glance. In many cases the injury is such that only a portion of the leaf surface is burned, comparatively little leaf shedding is caused, and the plants appear to recover completely in a day or two. In reality, however, a very slight degree of leaf burning may assume serious proportions because it causes sufficient plant disturbance to produce a heavy shedding of fruit.

In case of leaf injury the cause of which is doubtful, it is advisable to pick several affected leaves, pack them in a moist wrapper, and send them either to the Delta Laboratory or to the plant pathologist of the nearest State experiment station.

HOW TO APPLY POISON.

AMOUNT REQUIRED PER ACRE FOR EACH APPLICATION.

The quantity of calcium arsenate required for each application varies somewhat with the machinery utilized and with other conditions, such as the size of the plants, etc., but generally it has been found that at least 5 pounds per acre are necessary to make a satisfactory application. Where the machines are operated by experienced men, and especially by Government experts who have conducted this work for a number of years, it has been found that thoroughly satisfactory results can be secured by an average application of about 4 pounds per acre. But where the work is conducted upon a practical farm basis, the dosage used has averaged not less than 5 pounds per acre. Anyone attempting the operation for the first time is more likely to average in the neighborhood of 7 pounds per acre for each application. As calcium arsenate at present prices averages \$0.25 per pound, any reduction in the amount required for each application is quite an important item, but to be on the safe side it is advised that until farmers are more thoroughly familiar with the operation the application should be excessive rather than too light. Properly conducted, the operation has a very large margin of profit and it is poor economy to risk this profit by attempting to save a pound or two of poison per acre.

The greatest factor for further saving in the amount of poison required lies in the improvement of dusting machinery. The figures which have been quoted above apply only to the machines which are now in use in this work, and it is hoped that by further improvement of this machinery it will be possible to reduce the amount. In fact, considerable progress has been made in this respect. When the first experiments were started with power dusting machines it was found impossible to control the weevils on an acre of cotton with less than from 12 to 15 pounds of poison dust. If the dust could be broken up into its finest particles and efficiently distributed, there would be enough material in about every 2 pounds of poison to dust an acre satisfactorily, but the present machinery is not equal to the task of delivering the dust in this form. This matter is being studied very carefully with the hope that further improved machinery can be devised.

CONDITIONS UNDER WHICH TO MAKE APPLICATIONS.

The time of day for making these applications is quite an important point. Thoroughly successful results can be secured only when every part of the cotton plant is absolutely covered by the fine particles of poison dust. It has been found that when the humidity is low and there is any breeze whatever, the dust cloud will drift away above the cotton plants and will not filter down and cover all portions of the plant surface. The best time to dust is when the humidity is high, the air calm, and the plants moist with dew, so that the dust will adhere readily. This condition is experienced generally only at night and thus it has been necessary to do nearly all of the dusting work during the night, early in the morning, or late in the evening.

It has been found that while the weevils can be controlled by applications made under unfavorable conditions, the results are generally very erratic and unsatisfactory, and at best can only be expected to hold the weevils in check without accomplishing any considerable diminution in their numbers. This, of course, means that the application must be repeated at very short intervals and makes the entire operation very risky. Therefore the best economy undoubtedly is to reduce the acreage allotment of the different machines to the point where it is not necessary to operate when the plants are dry or while a breeze is blowing. This will increase the outlay for machinery, but it makes the entire operation much safer. Operation under unfavorable conditions should be attempted only in case of absolute emergency and fields which have been treated under such conditions should be watched carefully to determine whether the requisite degree of control has been secured.

ARRANGEMENT OF POISONING SCHEDULE.

Those features of poisoning which include the number of applications, the time of starting, time of ending, and time interval between applications are of course exceedingly variable and depend upon purely localized conditions. But a number of fundamental factors govern these points which should be understood in order properly to plan the operation. In the first place, as has been mentioned, a certain degree of weevil abundance may be permitted without resulting in any reduction in the cotton crop. Furthermore, it is necessary to control the weevils and hold them below the point of injury for only a limited time until the plants have had an opportunity to set their maximum crop. Another important point which must be considered in this connection is the fact that poison reaches and kills only the adult weevils present in the field and has no effect whatever on the imma-

ture stages developing in the bolls and squares. These immature stages continue developing every day for a considerable period after the application is made. A single application may tremendously reduce the adult weevils present in the field at that time, but they will be replaced very quickly by the new generation which is maturing and emerging. Unless the applications are repeated at the proper time intervals, therefore, freshly emerged weevils will soon become sufficiently abundant to counteract all the benefit which may have been secured from the first treatment. In some cases one or two applications may control the weevils sufficiently to permit the formation of a considerable crop of young bolls, but unless these bolls are protected by continued applications the weevils usually will multiply with sufficient rapidity not only to infest the squares present but also to prevent these young bolls from reaching maturity.

SEASON FOR APPLICATIONS.

When it was first found possible to kill at least a certain percentage of the weevils by poisoning, it seemed that the best results would be secured by early season applications, thus deriving the double benefit of killing the weevils then present and preventing the development of their potential progeny. Consequently the first tests were almost entirely early season applications. But it was soon found that far more profitable results were secured by treatments later in the season. Thorough studies on this point have since shown quite definitely that by far the greatest profit is derived by making the applications at the critical time when the weevil injury is just beginning to exceed the normal shed of the cotton plants. Another important point is that the plant is fruiting so rapidly at this time that every day of retardation of weevil infestation means a great deal in additional cotton production.

The time when poisoning should begin has almost no relation to the size of the cotton plant and is purely a question of weevil abundance. Such factors, however, as the size of the farm or field involved will determine very largely the basis upon which poisoning can be planned. For example, in some districts where the cultivated areas are large and more or less consolidated, weevil injury is very evenly distributed, owing to the fact that the weevil adults emerging from hibernation in the spring usually concentrate on the first fields they reach and do not seriously infest the more distant fields until they have practically overtaken the fruiting of this near-by cotton. This condition is found in many portions of the cotton belt and is particularly pronounced in the district where the majority of this Department's tests have been conducted in the past, namely, the Mississippi Delta region of Louisiana, Arkansas, and

Mississippi. Here the plantations are fairly large, usually involving at least 500 acres of cotton in a single organization and frequently a much larger area than this. Under such conditions the poisoning is conducted upon the heavily infested fields with a two-fold object: (1) To secure a reduction in weevil injury upon such fields, and (2) to reduce the numbers of weevils to the point where they will not migrate to the adjoining cotton. It has been found that by operating under such a system it is practically never necessary to poison the entire acreage. Complete economic control of the weevils for the entire acreage can be secured by concentrating on the most heavily infested cuts early in the season and thus preventing weevil multiplication and migration. This is particularly advantageous in that it distributes the cost of poisoning over a much wider area than would otherwise be the case. On the other hand, this system has the disadvantage, which will be discussed later, of requiring a rather complicated organization for conducting the poisoning work.

In districts where the cleared areas are smaller, or farther South where the weevil mortality is so low during the winter that hibernation is possible practically throughout the fields, a more generally distributed infestation is found early in the season and it becomes necessary to treat all fields alike. This is especially true in districts of small farms where the fields are comparatively small in extent and are more or less surrounded by weevil hibernation quarters. Under such conditions the only safe method of procedure is to poison the entire area alike, and this naturally requires a larger amount of poison per acre than is the case where it is necessary to poison only a portion of the crop.

TIME OF STARTING POISONING.

Many studies have been conducted upon the subject of determining the proper time for starting poisoning, but so far no thoroughly satisfactory simple method has been devised. In order to secure uniformity, in studies conducted during the past, a system of what is termed "percentage of infestation" has been utilized. This means the percentage of squares present in the field which are weevil-punctured. While this is fairly simple of determination, a certain amount of care is required if false conclusions are to be avoided. The method utilized throughout this work has been to examine a hundred or more squares at several points in a field—usually the four corners and the center, although this is not generally necessary under ordinary farming conditions. The percentage of these squares which are weevil-punctured is noted and serves as a basis for the poisoning operations. In this connection, however, it should be noted that weevil

injury is frequently distributed over the plants very unevenly, as the weevils display quite a pronounced tendency to concentrate on the upper portions of the plants, and percentage counts should be based on an examination of all squares on the plants rather than on squares examined at random on the upper portions. Naturally the percentage of injury which can be permitted varies with the stage of the cotton plant, but it has been found that usually, if 10 to 20 per cent of the squares are punctured early in the season, practically no harm results. The number of punctured squares gradually increases until later in the season as high as 60 per cent or more can be punctured without any reduction in crop yield. To put off poisoning until there is such a high percentage is not advisable, however, owing to the rapidity with which weevils multiply after they reach this point, and thus exhaust the square supply and start attacking the young bolls. The majority of the poisoning operations in the past have been planned so as to start when about 15 to 20 per cent of the squares were punctured and then to repeat often enough to prevent the infestation from getting above about 25 per cent until the crop is set and the bolls are safe from weevil puncturing. In some cases where it is particularly desirable to confine the weevils to a certain cut and prevent any chance of migration, it is well to start at a somewhat lower percentage and continue even later, but where the only object in view is the benefit to the particular cut poisoned, there is apparently little to be gained from starting applications before at least 15 per cent of the squares are punctured.

TIME INTERVAL BETWEEN APPLICATIONS.

The question of the time interval between applications is very important and one on which only conditional advice can be given, since it varies under different local conditions. In the past, once the applications were started they were generally made once a week as long as this seemed advisable or necessary. In reality, however, this selection of a time interval of one week was purely arbitrary and more recent results seem to indicate that in the majority of cases much better results can be secured by shortening this time interval. The effectiveness of a single application of calcium arsenate is decidedly limited in its duration. Its persistence on the plants naturally depends to a considerable extent on conditions prevailing at the time of application and immediately thereafter. In fact, while a very high percentage of control is secured during the first day of the application, this decreases the second day, and by the fourth day there is generally little or no effect. This short interval of effectiveness is due to two factors: (1) The poison is either washed or blown from the plants, and (2) new foliage is developed so rapidly that

after a few days a great deal of unpoisoned tissue is present, which thus reduces the chances of poisoning the weevil.

A four or five day time interval is best. This not only controls the brood of adults which were present when the applications were started, but also controls their progeny. Under average weather conditions the immature stages developing in the cotton forms at the time when an application is made will continue emerging over a period of at least 12 days. In other words, if the cotton can be kept poisoned thoroughly for a period of about 12 days, the weevils and their progeny are thoroughly controlled. Results vary of course with weather conditions but, generally speaking, two applications with a four-day interval have been found as effective as three or four applications with an interval of a week or more. If conditions are anywhere approaching normal about three applications with a four-day interval will usually reduce the weevil infestation to such an extent that it will be possible to stop poisoning, and in most cases this degree of control has been sufficient to persist during the remainder of the season. Another important point in this connection is that where a 7-day or 8-day interval is used and anything happens to interfere with the schedule, as it often will, the interval may be so extended that practically all control will be lost and the operation will become a complete failure; whereas, when the shorter interval is attempted, any mishaps will still leave the applications sufficiently close together to give a fair degree of control and the worst that can be expected is the necessity of making one or two extra applications.

It should also be taken into consideration that when the short interval is used the infestation can be permitted to become decidedly higher than would otherwise be safe. In other words, the control is so positive and the reduction of weevils so great that it is usually safe to permit the weevil practically to reach the point of becoming injurious to the cotton before making any application.

The machinery requirement must be considered very carefully in connection with the time interval between applications, as the acreage which can be handled by any particular machine is proportionately decreased as the interval is shortened. This of course increases the investment in machinery required per acre. But this cost is offset by the decrease in the number of applications necessary and the consequent reduction in cost of poison and labor. It is offset to an even greater extent by the better control secured and the resultant higher yield of cotton. Of course at present the machinery supply is decidedly short and machines are now high in price compared to what they will be in the future when their production is standardized, so it is quite a problem to determine just how much the acreage allotment for each machine can be reduced without making the ma-

chine investment per acre too high. On the other hand, it is undoubtedly the wisest policy to utilize methods which will give the greatest possible degree of control during the first few years when it is necessary for everyone to feel his way, more or less, in arranging the poisoning schedule. Consequently, it is urged that poisoning be attempted only under such conditions as will justify a sufficient machinery outlay to permit poisoning at about a four-day time interval.

NUMBER OF APPLICATIONS.

The question as to the number of applications is closely correlated with that of the time interval and is one which every man must decide for himself by experience, as the number will vary widely under different conditions. In the large Delta plantations, where the majority of the work has been conducted in the past, it has been found that weevil control throughout the season in the cuts most heavily infested and requiring the earliest treatment in the spring has necessitated from four to six applications with a time interval of one week. Other cuts more distant from hibernation quarters and thus more lightly infested required three, two, one, or no applications. In two years' work on thousands of acres handled on this basis, the average number of applications for all cotton acreage involved has been something less than two. Where infestation is more uniformly distributed at the outset and general poisoning is necessary, it has been found advisable to figure on an average of about four applications, and in case of an excessively rainy season, five or six applications. These figures are based on a one-week time interval, as this interval has been the one adopted in the majority of work so far. With a shorter time interval, however, control can be secured with about three applications. This office is now planning to open a number of small experiment stations in nearly all representative districts of the cotton belt. By conducting control tests at all of these at the same time it will soon be possible to designate much more definite rules of procedure under the varying conditions found in these different districts.

TIME TO STOP POISONING.

The time to stop poisoning has been more or less covered by the discussion of the number of applications but it is probably well to outline briefly the conditions governing this. The idea is to maintain weevil control below the point of loss to the crop long enough for the plants to set as many bolls as they can mature and also to protect these beyond the danger of weevil puncturing. Furthermore, there is nearly always a time when the plants cease to retain any more fruit. In many cases they not only discontinue squaring and blooming but shed the young bolls as fast as they are

formed. This usually means that the plant has reached the limit of its ability to mature fruit. Naturally there is no advantage in attempting to protect these forms, and poisoning during this period, if conducted after the retained bolls are sufficiently large to escape weevil injury, is bound to be profitless. The time when this condition is reached varies widely with the season as well as with the soil fertility, and these factors must always be taken into consideration in deciding whether additional poisoning is justified.

EFFECT OF RAIN ON AN APPLICATION OF POISON.

The effect of rain upon the application of calcium arsenate is a subject of much importance. Experience has shown that a certain amount of rainfall is desirable during the poisoning operations as it induces the formation of dew, makes conditions more nearly ideal for dusting, and apparently increases the amount of mortality secured from the applications. Poisoning operations have been conducted during periods of extreme drought when there was almost no dew formation, but under such conditions it has been very difficult to secure a thorough degree of control. On the other hand, excessive rain is detrimental, owing to the difficulty of getting the poison to stay on the plants long enough to control the weevils. This was especially true during some of the work in the extreme southern districts in 1919. The rains encountered in this work were excessive and in many cases occurred almost daily. Under such conditions weevil poisoning can easily become an absolute impossibility but, as far as that is concerned, such conditions make it practically impossible to raise cotton at all.

It has been found that when an application is made under unfavorable conditions and the plants are dry, even a slight shower occurring a short time later will wash off practically all the dust, while if conditions during the application are more favorable for a large quantity of the poison to adhere to the plants, a much heavier rain will not interfere seriously with the effect of the treatment. As a general rule it seems advisable to repeat an application immediately if a drenching rain falls within 24 hours after treatment. Until more information is secured on the subject, it undoubtedly will be best to follow some such rule as this, but the question of degree of weevil infestation and the conditions under which the application has been made should undoubtedly be considered in connection with the question of whether the application should be repeated.

STARTING POISONING IN THE PRESENCE OF A COMPLETE INFESTATION.

Many farmers make no move toward weevil poisoning until the crop is seriously infested and in fact almost totally destroyed by the

weevils. Then they want to get action immediately and desire to make a hurried purchase of calcium arsenate and dusting machinery to try to save the situation.

To secure control after the weevils have become excessively numerous and have punctured nearly all of the fruit is very difficult and usually involves the use of excessive dosages of poison at short intervals and, furthermore, requires an unusually large number of applications. Consequently the operation is very expensive at best and is also exceedingly hazardous. A very short delay under such conditions is extremely dangerous. The writers do not advise anyone to start poisoning under such conditions with a view of protecting the plants sufficiently to *permit the setting of a new crop*. Sometimes a certain amount of poisoning under such conditions is extremely profitable, as, for instance, when a fair crop of young bolls has been set but is still in danger of weevil attack, owing to the fact that the bolls have not yet developed beyond the point of injury. When the weevils become excessively abundant in such a crop they quite frequently not only overtake the square formation but also destroy a high percentage of the bolls, and poisoning at this time will often save the bolls which are already present on the plants. Since these bolls require protection for only a very short period, it is possible to make perhaps two applications under such conditions and thus retard the weevils sufficiently to eliminate injury to the bolls. It should be remembered, however, that this is quite a different proposition from starting in and attempting to control the weevils to the extent of permitting new squares to develop, bloom, form bolls, and reach maturity.

EARLIER SEASON TREATMENT OF ISOLATED INFESTATIONS.

The expense of weevil poisoning can be considerably reduced in many cases by localized treatment of the most heavily infested patches early in the spring. Often only a few acres in a large field will be infested early in the season. These may be distributed along a strip of timber or may adjoin barns, cabins, or other hibernation quarters. The weevils tend strongly to attack the largest plants available on emergence in the spring, and in case of any inequalities of soil fertility such as are very commonly found, it will generally be noted that the weevils will concentrate on the patches of larger cotton. Under any such condition it is often possible greatly to reduce the infestation of the entire field and to delay considerably the date of general poisoning by going into these isolated spots fairly early in the season and treating them thoroughly before the weevils have an opportunity to spread.

ORGANIZATION OF POISONING OPERATION.

The organization of the poisoning operation will differ considerably with variations in the size and type of the farm involved, but in general may be roughly classified into three groups: First, the large plantation operation where the poisoning is conducted by a separate organization on a wage basis, all crops being treated regardless of tenantry; second, the operation on a large plantation where the treatment of each crop is left to the individual tenant; third, the operation on the small farm where all the poisoning is conducted by the owner and his laborers.

The majority of the work which has been conducted by this department has been located on large plantations which are operated on a tenant basis. Under this form of operation each tenant is in a way an independent farmer in that he has a particular crop for which he is responsible, but at the same time he is operating under the direction of the plantation manager and deriving more or less support from the plantation, paying as a rule a certain proportion of the crop yield in lieu of rental. This condition complicates the poisoning situation. Some planters desire to purchase small-scale machinery for each tenant, leaving the treatment of his crop to the tenant and making this a part of the regular farming operations. Theoretically, the planter would seem by this arrangement to get the work done for nothing. In reality, however, the tenant's time is so fully occupied by his regular duties that he can conduct such work only by neglecting other necessary operations. Furthermore, it has generally proved impossible to get the operation properly conducted if left to the individual tenant. This not only means that the opportunity for weevil control is lost on their crops but that these fields become a menace to the adjacent cotton which may have been properly poisoned. *Weevil poisoning is a plantation and not an individual field proposition.* For this reason nearly all the dusting work which has been done in the past has been organized separately from the regular routine operations of the plantation. Separate labor is secured and assigned to the poisoning operations and applications are made regardless of tenantry or crop arrangement, and are based purely on the distribution of the weevils over the place. This calls for skillful supervision, and where the property is large, involving the use of a considerable organization, it is generally found advisable to employ a competent man to take charge. This arrangement is particularly desirable at the present time, since the operation is so new and there is still so much to be learned about the most economical means of procedure.

The farmer who cultivates his own crop, or at least does so to a considerable extent, is in much closer touch with the progress of

events on his place and has a much smaller area to consider. Under such conditions he can watch his cotton very thoroughly for weevil outbreaks and is usually fully informed on weevil distribution and abundance throughout his fields. Furthermore, under such conditions poisoning is a comparatively minor operation, and by the use of hand guns or small-capacity traction dusting machinery it is possible for him to fit the weevil-poisoning work into his regular operations and handle it with little or no interference. Of course, as a rule, his fields are smaller than on a large plantation and thus it is usually necessary for him to poison his entire crop.

In a number of instances several neighbors have planned to enter into some agreement and purchase a traction-power machine cooperatively with the idea of treating their several crops with the same machine. Theoretically this arrangement seems a very good one, but there is considerable room for doubt concerning its practical working. As has been pointed out, weevil poisoning is generally an emergency proposition and the work must be done at the right time or the entire operation may be imperiled. Consequently, the situation which would develop in case the weather should interfere with a set schedule for machine operation on several places can easily be imagined. Crops belonging to the different men would require treatment at the same time and it would simply be contrary to human nature if friction did not develop under such conditions.

DUSTING MACHINERY TO USE.

The selection of proper dusting machinery is undoubtedly equally as important as securing the correct poison. At the outset of the poisoning work an attempt was made to utilize or adapt existing types of dusting machines such as have been used for truck crops or orchard dusting, but it was soon found that cotton dusting required highly specialized machinery. All dusting operations which had been conducted previously had been in conjunction with more or less intensively handled crops where the labor supply per acre was generally rather plentiful and where the labor was of a fairly intelligent type. In the culture of cotton, however, dusting is placed on an extensive basis where it becomes a large field operation and the machinery must be made as efficient, fool-proof, and simple as possible.

The success of cotton dusting is so dependent on thorough distribution of the poison that any attempt to utilize a means of application which does not give this thorough distribution is certain to result in absolute failure. Many farmers have been accustomed to use the "bag-and-pole" method of poisoning for leafworm control. Such a method of application is suited to leafworm control where large

areas of plant tissue are devoured by the insects and the chances of poisoning considerably increased, but it will not furnish a sufficiently thorough distribution to result in control of the boll weevil.

A special Farmers' Bulletin (1098) has been issued by the Department of Agriculture on the subject of dusting machinery for the cotton boll weevil, and everyone contemplating poisoning is advised to secure a copy of this and study it thoroughly.

So far only three types of satisfactory dusting machines have been developed and placed on the market, namely, the hand gun, the wheel-traction machine, and the engine-power machine.

HAND GUN.

Several satisfactory models of hand guns are now on the market and may be purchased at from \$15 to \$25 each. Each machine consists of a small hand-operated fan and hopper slung from the shoulder of the operator, which is carried through the field, poisoning a single row of cotton at a time. Unfortunately these machines are very difficult to operate. The labor involved is strenuous, to say the least, since the operator must walk through the field at a very fair pace and bear the strain of carrying, directing, and cranking the machine. It has been found that operating for a short period of time, a man can cover about an acre an hour with one of these guns, but he can not continue at this rate for more than an hour or so. Owing to the necessity of poisoning when the plants are moist with dew, hand-gun work can usually be conducted only during the early morning or late evening. Generally speaking, this means from about 4 or 5 o'clock until 8 or 9 in the morning, and from about 6 o'clock to dark in the evening. About the best speed that can be attained is in the neighborhood of 5 acres per day for each man. If two men are available for each gun, it is possible to change occasionally and thus speed up the work so that the area covered by the single gun during the day is somewhat increased, but even under such conditions it is hardly safe to count on an average of more than 5 acres per day for each machine. Figuring on a four-day time interval, this would mean that each machine would cover about 20 acres, but in reality, with loss of time due to various causes which is certain to be experienced, and with delay due to inability to operate under unfavorable conditions, it is certainly not safe to figure on an average allotment of more than 15 acres to each hand gun. It would undoubtedly be much better to figure on about 10 acres for each hand gun, and, if possible, to distribute the operation of this gun between two different laborers.

In many cases farmers planting from 40 to 100 acres of cotton do not feel justified in purchasing large machines and desire to under-

take weevil poisoning by the use of a number of hand guns on this area. This has generally proved very unsatisfactory. The labor requirements of the guns are so great and the operation so laborious and difficult that labor troubles are certain to develop under any normal condition and this has generally resulted in preventing anything like a satisfactory schedule for poisoning work.

One important use of the hand gun is in conjunction with power machinery. A great many fields have certain portions which are very difficult to treat with power machinery, owing to the presence of ditches, stumps, short rows, or similar obstacles. Attempts to treat these portions of the fields with large machinery greatly reduce the rapidity of the operation of the machine and frequently the cotton is injured by being tramped and driven over. Under such conditions the efficiency of the large machine is much increased if a few hand guns with which to treat these difficult portions are available for use at intervals.

Hand guns are also of great value for the early-season work in treating isolated spots of infestation which are often comparatively small in extent. In much of the work which has been conducted in the past, hand guns have been used in such fields for the first application or two and a sufficient degree of control secured from this work to make it possible to defer starting general poisoning with a large machine until some weeks later than would otherwise have been the case.

Several instances have been noted where hand machines have been offered for cotton dusting purposes with the distributing system divided between two nozzles, the idea being that two rows could be treated at each trip. None of the machines manufactured at present have more than enough fan power to treat a single row satisfactorily.

A number of hand guns have been offered for use in cotton dusting with the blower constructed so that the dust delivery is intermittent. As such guns are usually equipped with a bellows serving as a blower the powder is expelled only in recurrent blasts. These are not satisfactory for cotton work since it is necessary that the gun discharge the dust continuously in order that uniform poisoning of all plants be secured while the operator proceeds along the row.

As has been stated, hand-gun work is mainly conducted in the early morning and late evening, and this limits very much the amount of territory which can be covered each day. Operation during the night, however, is often entirely feasible and the results from such operations are usually better than where treatments are attempted during the day. Very satisfactory hand dusting can be done at night by the aid of a small oil or carbide light attached to the hat of each operator, or, in some cases, several hand guns may be

worked together as a group if some kind of torch or contractor's flare is placed at the row ends to provide light.

Another way of reducing the amount of labor involved in hand dusting is by the operation of the machine from muleback. This has been tried on numerous occasions and is generally much more satisfactory than by walking.

POWER DUSTERS.

The earliest work on weevil poisoning was conducted entirely with hand guns, as very small areas were treated during the strictly plat-test stage of the work. Ordinarily the next step in development of dusting machinery would have been to produce something of slightly larger capacity, but owing to the rapid development of the work at this stage, attention was transferred from the development of hand guns to that of blowers of the largest possible capacity, namely, the engine-power machines. In this case the duster was a horse-drawn machine with the fan and feeder operated by a small gasoline engine mounted on the platform. This machine had a distributor extending across the rear end with five nozzles spaced $4\frac{1}{2}$ feet apart, thus covering approximately five rows. Several models of these machines were devised and placed on the market and were used rather extensively during 1918 and 1919. It was found that they would cover from 6 to 10 acres an hour while in operation but that the loss of time due to mechanical difficulties was so great that a machine seldom averaged over 40 or 50 acres for the day's operations. Continued use of these machines soon made it obvious that they were too complicated and cumbersome to be thoroughly satisfactory for cotton-dusting work. Probably the most serious difficulty was the gasoline engine. Another great difficulty was found in constructing a thoroughly satisfactory distributing system for spanning five rows. There was considerable length of pipe extending out beyond the machine on both sides and as this was necessarily made very heavy, the weight caused almost constant breakage due to excessive vibrations and jarring. In many cases the distributors of these power dusters were cut off so as to cover only three rows at a time and they really treated more acreage throughout the season than when they were arranged to span five rows, owing to the greater convenience in handling the machine over the field, around stumps, fences, etc., and the decreased loss of time from breakage.

These power machines were placed on the market at prices ranging from \$400 to \$600 and this price seemed high for the work they could accomplish. Consequently it was desirable to devise a machine which would eliminate the gasoline engine and span only three rows

with its distributor and which could be sold at a more reasonable price. The only answer to this problem which has been developed so far is the wheel-traction or cart type of duster.

WHEEL-TRACTION OR CART DUSTERS.

For the wheel-traction duster a light two-wheel cart is utilized and the power for driving the fan, feeder, etc., is derived from the wheels of the cart. This duster is pulled by two mules and is operated by one man instead of two. By the beginning of 1919 a tentative model had been produced which was placed in the field and operated on a practical basis throughout that season. This machine proved eminently satisfactory in spite of the fact that it was very crudely constructed, and it was selected as the most desirable type for general use in cotton dusting on a large scale. As built, it proved far simpler and easier to operate than the power machines and was especially valuable for its convenience in driving through the field. A number of duster manufacturers became interested in this type of machine and several models based somewhat on this idea are now on the market and others are in the course of construction. These differ widely and embrace the ideas of individual designers, but the general principles of construction are more or less the same. Practically all of the machines are built with an arched axle providing a 42-inch clearance beneath the arch and having a tread of about 48 inches, thus enabling satisfactory operation in any cotton rows not narrower than about 36 inches.

It has been found that under normal conditions one of these wheel-traction machines will probably average about 25 acres per night of operation. It may exceed this amount under very favorable conditions but it is not safe to figure on a greater average than this. As has been pointed out, it is undoubtedly desirable to provide equipment for treatment at a time interval of about 4 days. Owing to rains and other interruptions, it is undoubtedly not safe to figure on more than three days' operation out of the four. Consequently, about the best that can be expected of one of these machines is that it will handle in the neighborhood of 75 acres of infested cotton throughout the season.

So far the machines of this type which have been built have been placed on the market at a rather high price, ranging from about \$350 to \$500. The manufacturers have taken extreme precautions to place the highest quality of workmanship and material in the construction and this has resulted in making the price of the machine higher than is generally desirable. It still remains to be seen whether or not this cost is justified by increased efficiency of the machines. It seems quite probable that other machines built on

much the same design will be placed on the market at a fairly early date at a lower figure. From present prospects the minimum sales price for such a machine will be in the neighborhood of \$200.

The high cost of this machinery is particularly unfortunate, as it will tempt the farmer to expand his acreage allotment for each machine as much as possible by increasing the time interval between applications. This is bound to be a hazardous practice. In fact, if a grower is confronted with the problem, it would be far better for him to select a limited acreage of his best yielding land where the weevil damage is highest and treat this thoroughly and properly, ignoring the rest of his crop, than risk the success of the entire operation by attempting to make a machine cover too much acreage.

NEED OF AN INTERMEDIATE TYPE OF DUSTING MACHINE.

As the situation now stands, there is no dusting machine on the market intermediate between the hand duster and the wheel-traction or cart type of duster. Inasmuch as hand dusters are generally unsatisfactory on fields larger than about 25 acres, and as the cost of a cart duster is such that a man is seldom justified in buying one for use on less than 75 acres, no equipment suitable for a man cultivating between 25 and 75 acres of cotton is available and his problem is a difficult one. When a sufficient supply of labor is available, however, it may be possible for him to utilize hand guns; and where the soil fertility is particularly high, the purchase of a cart machine for use on the small acreage may be justified. Several types of devices, such as saddle guns or single-wheel machines for operation between the cotton rows, are being studied, but the process of perfecting and producing them will require considerable time.

LIGHTING EQUIPMENT FOR DUSTING MACHINES.

The question of lighting any cotton-dusting machine requires particular attention. As has been explained, an application of poison gives the best results when it is made at night; therefore a thorough lighting equipment must be provided. This has been a serious difficulty in the past and all kinds of lights have been tested. So far only one type has been developed which gives any assurance of being thoroughly satisfactory. This is a special model of acetylene light which utilizes a compressed carbide cake for fuel. These lights have been constructed for cotton-dusting machine work and apparently the majority of the machines to be placed on the market will be equipped with them. At any rate, anyone purchasing a dusting machine should be sure that it is provided with a simple and satisfactory equipment that will give ample light for avoiding stumps,

ditches, etc., while driving. It must also afford sufficient rear illumination over the nozzles to enable the operator to make sure that the dust flow is regular.

CAPACITY OF MACHINES FOR TREATING SEVERAL ROWS PER TRIP.

In the earlier stages of the work it was attempted to make machines with adjustable nozzles that could be aimed directly at the rows being treated. It was soon found, however, that cotton rows vary so greatly in spacing that such an arrangement was impractical. Moreover, it was unnecessary. The entire poisoning operation is based on the plan of creating a thick cloud of dust which will envelop all parts of the cotton plants and coat them thoroughly. Consequently, all width-adjusting devices were eliminated and the nozzles have since been spaced about $4\frac{1}{2}$ feet apart. These nozzles are provided with deflecting plates or some similar spreading device which causes the dust clouds from the different nozzles to unite very quickly after leaving the machines, so that a uniform "fog" extending from row to row is created. Under such conditions it does not matter whether the nozzles are directly over the rows or between them. It has also been found possible under certain conditions to cover more rows than the nozzles actually span. This suggestion, however, should be taken very conservatively, as considerable experience is required in the use of dusting machinery to determine just how far the drift can be considered as thoroughly effective in dusting. Until the operators have become thoroughly experienced in this work it is probably the best plan to figure on taking only as many rows as the distributor will actually span.

FEATURES TO BE NOTED IN PURCHASING COTTON-DUSTING MACHINERY.

For the benefit of those planning to purchase cotton-dusting machinery, the following brief outlines have been prepared giving the most important features which should be considered in order to make sure that the machines will be satisfactory.

HAND GUN.

The total weight should be not over 20 pounds when filled with poison dust.

The hopper should hold about 4 to 7 pounds of calcium arsenate and it should be possible to put out practically all of this before refilling.

The balance of the gun should be such as to cause the least strain on the operator, that is, the heavy parts of the machine should be as close to his body as possible.

The gun should hang naturally so that the nozzle is directed at the tops of the cotton plants without causing any undue strain on the operator in aiming it.

The capacity of the feeding mechanism should be sufficient to permit the use of a delivery of at least 1 pound in 5 minutes at the ordinary rate of cranking.

The feed should be quickly and positively controlled. Adequate facilities should be provided for lubrication of working parts.

The fan should create sufficient air current to break up the dust into a cloud and force it to spread over all parts of the plant.

The gun should be well constructed throughout so that breakage is reduced to a minimum.

All parts of the gun should be as conveniently accessible as possible for repair or replacement.

WHEEL-TRACTION OR CART DUSTER.

The wheel-traction machine should be light enough in weight and draught to enable an average team to operate it through a full night without undue fatigue.

There should be sufficient axle clearance to avoid plant injury.

The tread should be such that it will straddle a row of cotton without running on the adjacent ones and still prevent the machine from being dangerously top-heavy.

The machine should be properly balanced on the axle to prevent uptilting of the tongue or undue strain on the necks of the team.

All details of construction should be simple, fool-proof, and durable.

The feed mechanism should be subject to quick and positive regulation, varying from a complete cut-off to a maximum delivery of 6 pounds in 5 minutes through the three nozzles at the ordinary rate of walking for the team.

The fan should create sufficient air blast to prevent clogging of the pipes, and to blow the dust throughout the plants under any ordinary weather condition.

The machine should be provided with suitable lighting equipment.

The hopper capacity should be sufficient to hold from 30 to 50 pounds of calcium arsenate.

The distributing system should be provided with a positive lift to regulate the height of the nozzles from vertical to horizontal and should also be arranged to fold in conveniently to permit passage through gates.

The platform should be large enough to accommodate all machinery and the driver and also to carry a barrel of poison.

The driving mechanism should be so arranged that the fan will continue in operation while the machine is turning on one wheel in either direction at row ends.

The running and driving mechanism should be shielded to prevent plant injury or clogging with vegetation.

The method of hitching should allow flexibility which will prevent the load from being thrown on one animal.

All parts should be readily accessible for repair or replacement.

POWER DUSTER.

The engine of a power duster should be as simple and efficient a type as possible and should provide a slight surplus of power over that actually required to operate the machinery.

The truck should be provided with a fifth wheel arrangement and the front wheels should cut under the body to permit short turns.

The distributor construction should be strong enough to carry the wide spread of nozzles.

COST OF POISONING.

Anyone who has read the preceding pages carefully can easily appreciate the futility of attempting to give generalized figures on the cost of poisoning which would be of any value to the individual. The cost to each man is going to be an individual problem and will differ radically in the different fields and in different seasons. Although careful cost figures have been kept in connection with the experiments which have been conducted in the past on both large and small scale work, it is useless to give more than a few generalized statements concerning these. Where the operation has been conducted on an individual field basis requiring in the neighborhood of four applications, it has been found that the cost of poison, labor of application, and reasonable depreciation on the investment for machinery has been in the neighborhood of \$7 to \$10 per acre for the season. On a large plantation basis the investment in poison and machinery has naturally been lower but the additional cost of supervision, etc., has generally been sufficient to offset this difference. At present prices, it is hardly safe to figure on a cost of less than \$2 an acre per application.

GAINS TO BE EXPECTED FROM POISONING.

The gain in amount of seed cotton to be expected from the use of poison is another point which is not subject to definite figures. During the past five years several hundred plat tests have been conducted in such a manner that an accurate comparison in yields was

afforded between the poisoned and unpoisoned plats. Throughout this work the gains have varied from nothing to over 1,000 pounds of seed cotton per acre.

The most that can be expected of poisoning is the elimination of weevil injury. Soil fertility is very important and really becomes the determining factor in the amount of gain which can be secured from the poisoning. One interesting feature of the work which has been conducted so far is the large number of tests on fields which had a fairly low degree of weevil infestation and which have shown absolutely no gain from the operation. In many cases comparable plats have been selected and started with an infestation of 10 or 15 per cent, one plat being poisoned and the other left unpoisoned as a check. In such cases, the infestation of the check plat, instead of increasing as would normally be the case, has been held in check by some climatic condition so that there was only a gradual increase to a maximum of from 35 to 50 per cent of the squares punctured at the end of the season. Usually, under such conditions, no gain in yield is shown in spite of the fact that infestation of the poisoned plat was practically wiped out. In other words, the degree of infestation in the check plat was not sufficient to overtake the normal shed of squares and thus there was no reduction in crop yield. This, of course, illustrates the needlessness of poisoning unless the weevils are sufficiently abundant to injure the crop.

There are many fields where weevil infestation becomes so complete by the middle or latter part of the summer that it would seem advisable to start poisoning, but the plants in these fields may have reached the limit of their production on that soil, thus being unable to take advantage of any protection from weevil attack. This is particularly true of many of the sandy soils upon which the plant produces a very quick crop of cotton and then matures and stops fruiting at an early date. This point is further complicated by variations in the habits of the different cottons. For example, certain varieties of cotton have what is ordinarily termed a "determinate" growth. They make their crop early and then stop fruiting altogether. Consequently, any poisoning under such conditions, regardless of the degree of weevil control secured, is a useless expense unless undertaken for the protection of the young bolls already set on the plants.

In still other cases there are soils of such low potential productivity that even if the entire crop were saved from destruction by the weevil its value would still not justify the expense of poisoning.

To summarize the results of the experiments which can be considered of real value in this connection, it may be said that the actual gains in seed cotton per acre have ranged from about 200 to 1,000

pounds. In these cases the infestation was heavy enough to justify the treatment, and, furthermore, the soil was generally of a decidedly fertile nature. In reality these figures are quite conservative, as they are based on very small plat tests where there was undoubtedly considerable reduction in gain due to the effect of weevil migration from nonpoisoned cotton. This is shown by the general results of a considerable number of the large-scale tests conducted under conditions more or less the same. Unfortunately in large-scale tests accurate figures can not be secured on the increase of yields, but it is obvious from the approximate comparisons made that the gains were very large, being, in fact, considerably larger than those obtained in plat tests under the same conditions. Consequently it seems safe to assume that with fertile soil and a fairly severe weevil infestation average gains of 500 pounds or more of seed cotton per acre are not at all remarkable.

ADVISABILITY OF POISONING UNDER PRESENT CONDITIONS.

The first thing which must be decided by any one contemplating poisoning is whether or not his conditions are such as will enable the operation to be profitable. In case of doubt it would be best for him to forego poisoning. As has been shown, weevil infestation must necessarily be at least fairly severe. Furthermore, the soil fertility must be such that the plants can take advantage of the protection afforded them by poisoning and produce a considerable gain in yield. It is difficult to establish any fixed limits with regard to soil productivity, but for the present at least it hardly seems advisable to attempt poisoning unless the land would make at least half a bale of cotton per acre in case there were no weevils. In fact, if the higher-priced machinery, such as has been mentioned, is utilized, it will probably be advisable to raise this limit somewhat and poison only land capable of making two-thirds or three-fourths of a bale of cotton. This naturally means that a very large proportion of the hill-land cotton will not justify poisoning at present, as the soil fertility is too low. Nearly all hill farmers, however, have at least a few acres of fertile bottom land in their farms which can be utilized for small-scale poisoning work during the first year or two to afford experience in poisoning which will make it safer for them to expand the work later over the remainder of their crop. In fact, regardless of conditions, unless a man is thoroughly sure of being able to conduct the operation just as outlined, it is undoubtedly best for him to undertake it first on only a portion of his cotton, selecting for this purpose the most fertile soil which is subject to the heaviest weevil injury.

A very accurate check plat should be provided; otherwise the question of gain or loss is likely to be more or less problematical. For this purpose several fairly uniform cuts should be selected, subject to about the average degree of weevil infestation in that locality, and only one-half of each cut treated, letting the remainder go untreated as a check on results secured. A little experience of this sort will soon make clear the conditions under which the grower can or can not poison profitably. Of course, this unpoisoned check plat will serve to increase the infestation of the adjacent poisoned cotton, but this slight loss will be far more than offset by the value of the information secured.

Weevil poisoning has in some cases been criticized as possibly tempting the farmer to neglect securing the proper varieties of cotton and cultivating properly, and other important factors or operations which have been learned as a result of hard experience with the boll weevil. On the contrary, by eliminating weevil injury it should encourage the planter to strive for the increased yield which can be induced by good farming, and to emulate the man who practices such a good method of farming that his gain from weevil poisoning is tremendously increased. *No one should slight any other operation involved in the production of the cotton crop just because the plants are being poisoned.* Weevil poisoning can not make cotton. It is up to the farmer and the land to do this, and the best that can be expected of poisoning is to save this cotton from weevil destruction.

CONTROL OF THE COTTON LEAFWORM AND FALL ARMY WORM WITH CALCIUM ARSENATE.

One question which frequently arises in connection with the use of calcium arsenate is whether or not this material will control the cotton leafworm, fall army worm, or any other pests of this nature. It will undoubtedly be as satisfactory for this purpose as any chemical which could be utilized. It is very nearly as poisonous as Paris green to the worms and has the decided advantage of being cheaper and less injurious to the plants. In case anyone desires to utilize weevil-poisoning equipment solely for leafworm control, however, he should bear in mind that he could considerably reduce the expense of the operation without interfering with its effectiveness by mixing equal parts of lime and calcium arsenate and applying this mixture at the rate of about 4 or 5 pounds per acre.

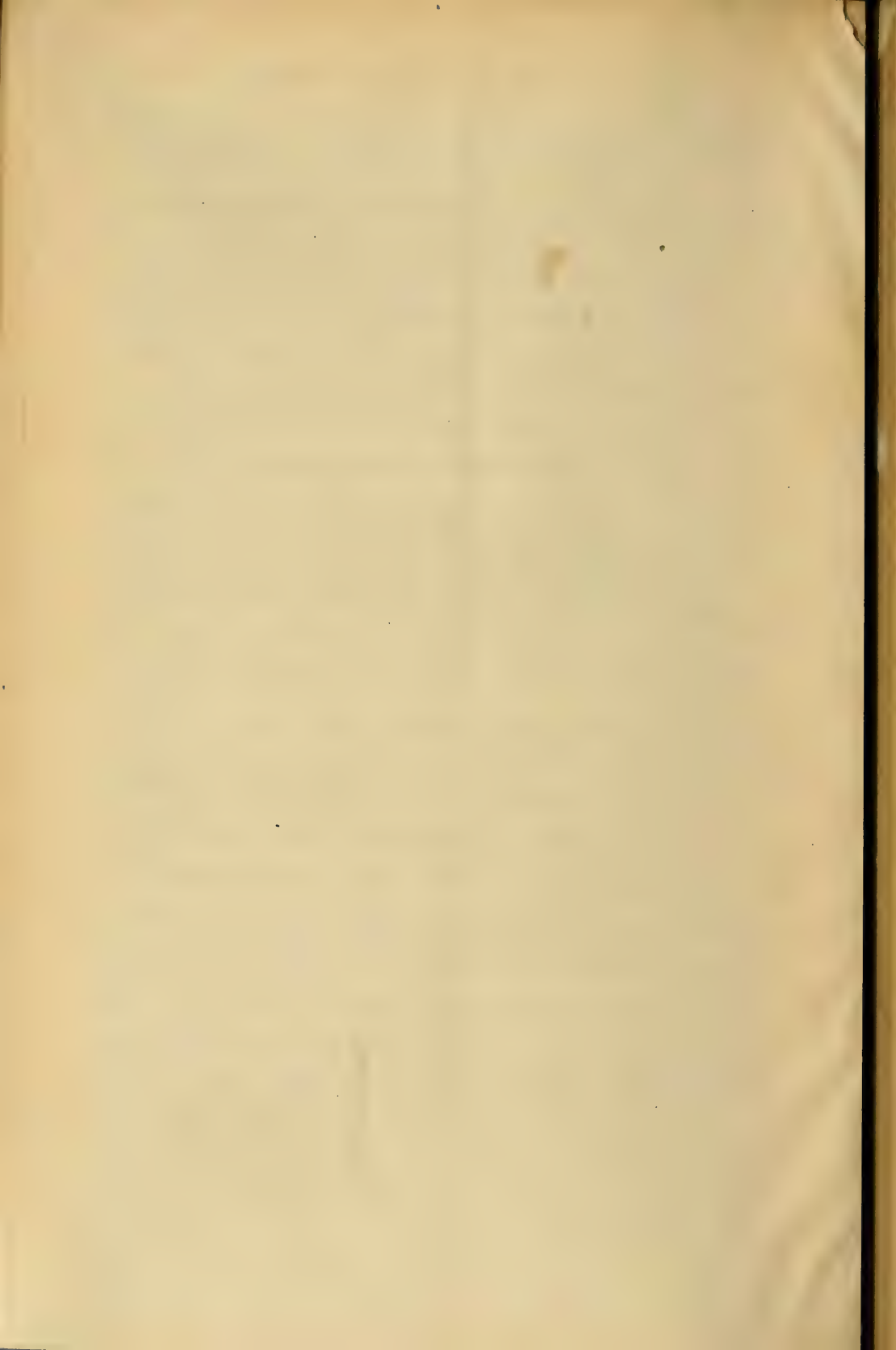
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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 851

Office of the Secretary
Contribution from Office of Farm Management
H. C. TAYLOR, Chief

Washington, D. C.

July 30, 1920

COST OF PRODUCING APPLES IN FIVE
COUNTIES IN WESTERN
NEW YORK, 1910-1915

By

G. H. MILLER, Assistant Agriculturist

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 852

Contribution from the Bureau of Public Roads
Thos. H. MacDonald, Chief

Washington, D. C.

PROFESSIONAL PAPER

October 28, 1920

THE FLOW OF WATER IN CONCRETE PIPE

By

FRED. C. SCOBEE, Senior Irrigation Engineer

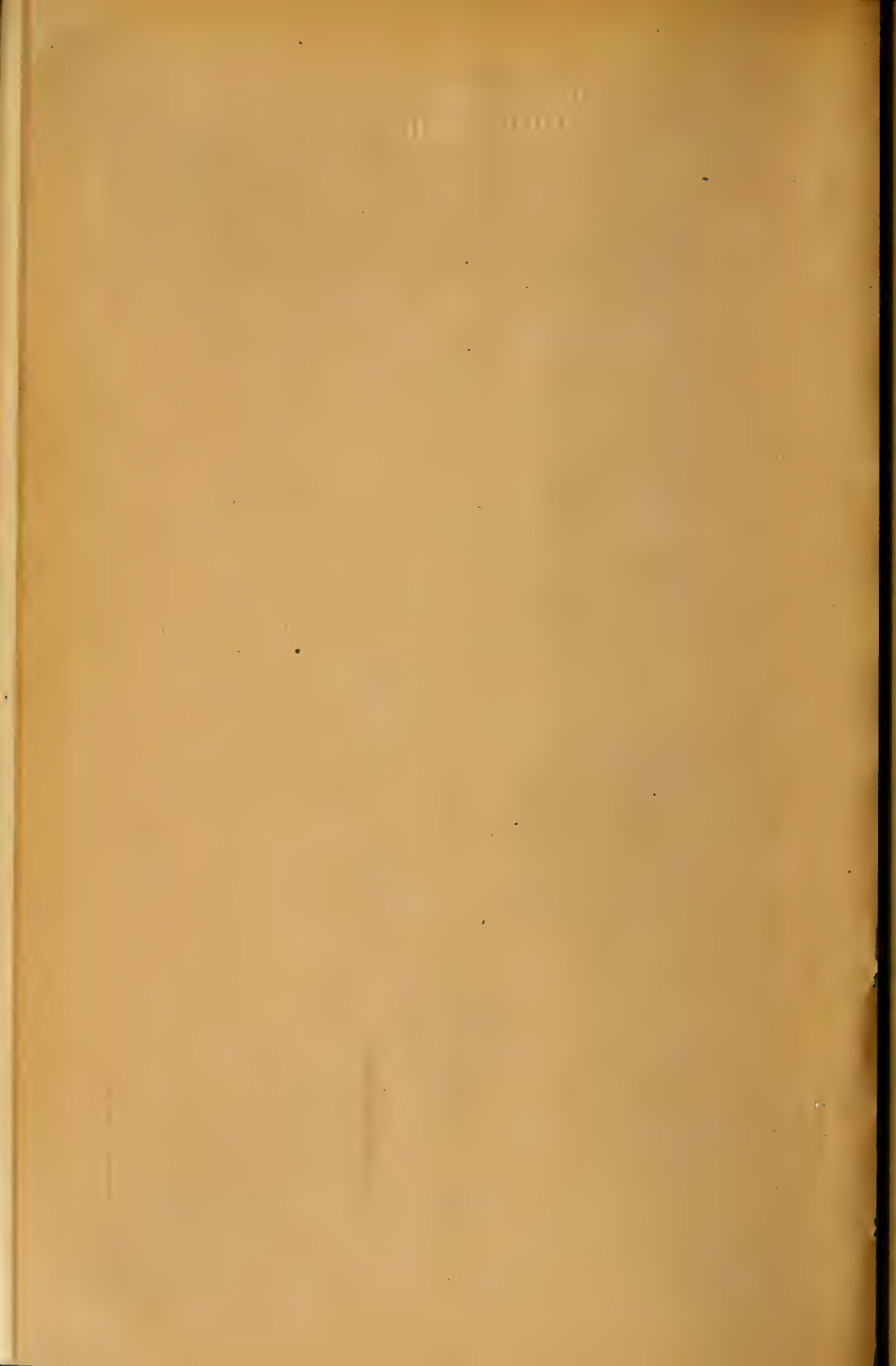
With Discussion by KENNETH ALLEN, ARTHUR S. BENT, F. C. FINKLE,
ALLEN HAZEN, J. B. LIPPINCOTT, and H. D. NEWELL

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 853

OFFICE OF THE SECRETARY

Contribution from the Office of Farm Management
H. C. TAYLOR, Chief

Washington, D. C.

July 20, 1920

THE
ORGANIZATION AND MANAGEMENT
OF FARMS IN NORTHWESTERN
PENNSYLVANIA

AN ANALYSIS OF THE BUSINESS OF 422 FARMS
IN THE VICINITY OF GROVE CITY, PA.

By

EARL D. STRAIT, Scientific Assistant
H. M. DIXON, Assistant Agriculturist

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 854

Contribution from the Bureau of Public Roads
THOS. H. MACDONALD, Chief

Washington, D. C.

PROFESSIONAL PAPER

August 26, 1920

THE FLOW OF WATER IN DRAIN TILE

By

D. L. YARNELL, Senior Drainage Engineer, and SHERMAN M.
WOODWARD, Professor of Mechanics and Hydraulics
State University of Iowa

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 859

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief.

Washington, D. C.



September 7, 1920

THE PROCESS OF RIPENING IN THE TOMATO, CONSIDERED ESPECIALLY FROM THE COMMERCIAL STANDPOINT

By

CHARLES E. SANDO

Formerly Junior Chemist, Horticultural
and Pomological Investigations

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 860

Contribution from the Bureau of Markets
GEORGE LIVINGSTON, Chief

Washington, D. C.



August 20, 1920

THE ORGANIZATION OF COOPERATIVE
GRAIN ELEVATOR COMPANIES

By

J. M. MEHL, Investigator in Cooperative Organization, and
O. B. JESNESS, Specialist in Cooperative Organization

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 861

Contribution from the Bureau of Markets
GEORGE LIVINGSTON, Chief

Washington, D. C.



September 13, 1920

MARKETING EASTERN GRAPES

By

DUDLEY ALLEMAN, Assistant in Market Surveys

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THE changes brought about by recent legislation should not injure the grape industry of the North and East if the crop is handled in a careful and businesslike manner from the vineyard to the consumer.

The vineyardist should produce the varieties demanded by the trade in his section, should prepare his product for the market according to the most approved methods, and should choose his marketing agency with care.

The shipper should devote his attention to the intensive and extensive distribution of the crop with a view to supplying each chosen market with the variety and quantity in demand.

All city handlers should work for the quick movement of the grapes from car door to consumer and for the stimulation of the demand as supplies increase.

To aid each of these groups in solving the problems involved and to aid in preserving the profitable status of the grape industry is the purpose of this bulletin.

UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 862

Contribution from the Bureau of Biological Survey
E. W. NELSON, Chief

Washington, D. C.

PROFESSIONAL PAPER

December 30, 1920

FOOD HABITS OF SEVEN SPECIES OF
AMERICAN SHOAL-WATER DUCKS

By

DOUGLAS C. MABBOTT, Assistant in Economic Ornithology

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 863

Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C.

PROFESSIONAL PAPER

September 30, 1920

FORESTRY LESSONS ON
HOME WOODLANDS

By

WILBUR R. MATTOON

Extension Specialist in Forestry, Forest Service
and

ALVIN DILLE

Specialist in Agricultural Education, States Relations Service

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 865

Contribution from the Bureau of Markets
George Livingston, Chief

Washington, D. C.

August 16, 1920

A CLASSIFICATION OF
LEDGER ACCOUNTS FOR CREAMERIES

By

GEORGE O. KNAPP and BURTON B. MASON, Assistants
in Market Business Practice, and A. V. SWARTHOUT
Investigator in Market Business Practice

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 866

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C.

August 24, 1920

PICKERING SPRAYS

By

F. C. COOK, Physiological Chemist
Insecticide and Fungicide Laboratory

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 867

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

September 3, 1920

THE CASTOR-OIL INDUSTRY

By

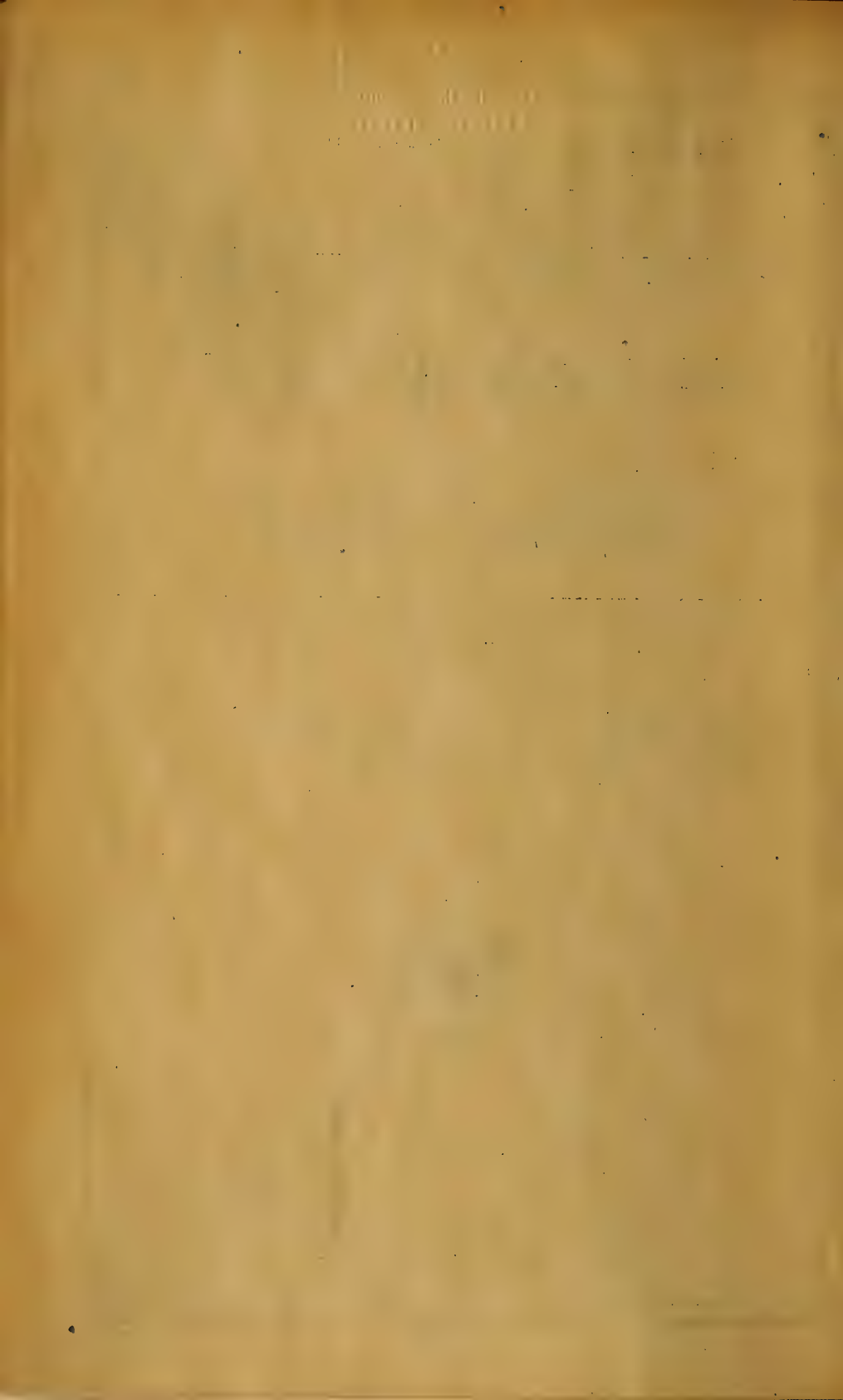
J. H. SHRADER, formerly Chemical Technologist, Office of Drug,
Poisonous, and Oil Plant Investigations

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 868

Contribution from the Bureau of Biological Survey
E. W. NELSON, Chief

Washington, D. C.

PROFESSIONAL PAPER

January 10, 1921

ECONOMIC VALUE OF THE STARLING
IN THE UNITED STATES

By

E. R. KALMBACH and I. N. GABRIELSON

Assistant Biologists

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 869

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

September 30, 1920

THE INHERITANCE OF THE LENGTH
OF INTERNODE IN THE RACHIS
OF THE BARLEY SPIKE

By

H. K. HAYES, Head of Section of Plant Breeding, Division of
Agronomy and Farm Management, College of Agriculture, Uni-
versity of Minnesota, and HARRY V. HARLAN, Agronomist in
Charge of Barley Investigations, Office of Cereal Investigations

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 871

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

November 10, 1920

THE DRY-ROT OF INCENSE CEDAR

By

J. S. BOYCE, Assistant Pathologist
Office of Investigations in Forest Pathology

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 872

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

November 11, 1920

INSECT CONTROL
IN FLOUR MILLS

By

E. A. BACK, Entomologist in Charge of Stored-Product
Insect Investigations

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BULLETIN No. 873

Contribution from the Bureau of Markets
GEORGE LIVINGSTON, Chief

Washington, D. C.

September 15, 1920

THE SHRINKAGE OF
MARKET HAY

By

H. B. McCLURE
Specialist in Hay Marketing

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 874

Contribution from the Office of Farm Management and Farm Economics

H. C. TAYLOR, Chief

In Cooperation with the Iowa Agricultural Experiment Station

C. F. CURTISS, Director

Washington, D. C.

PROFESSIONAL PAPER

August 23, 1920

FARM LAND VALUES IN IOWA

By

L. C. GRAY, Agricultural Economist in Charge
of Land Economics, Office of Farm Management
and Farm Economics

and

O. G. LLOYD, Assistant Chief in Farm Management
Iowa Agricultural Experiment Station

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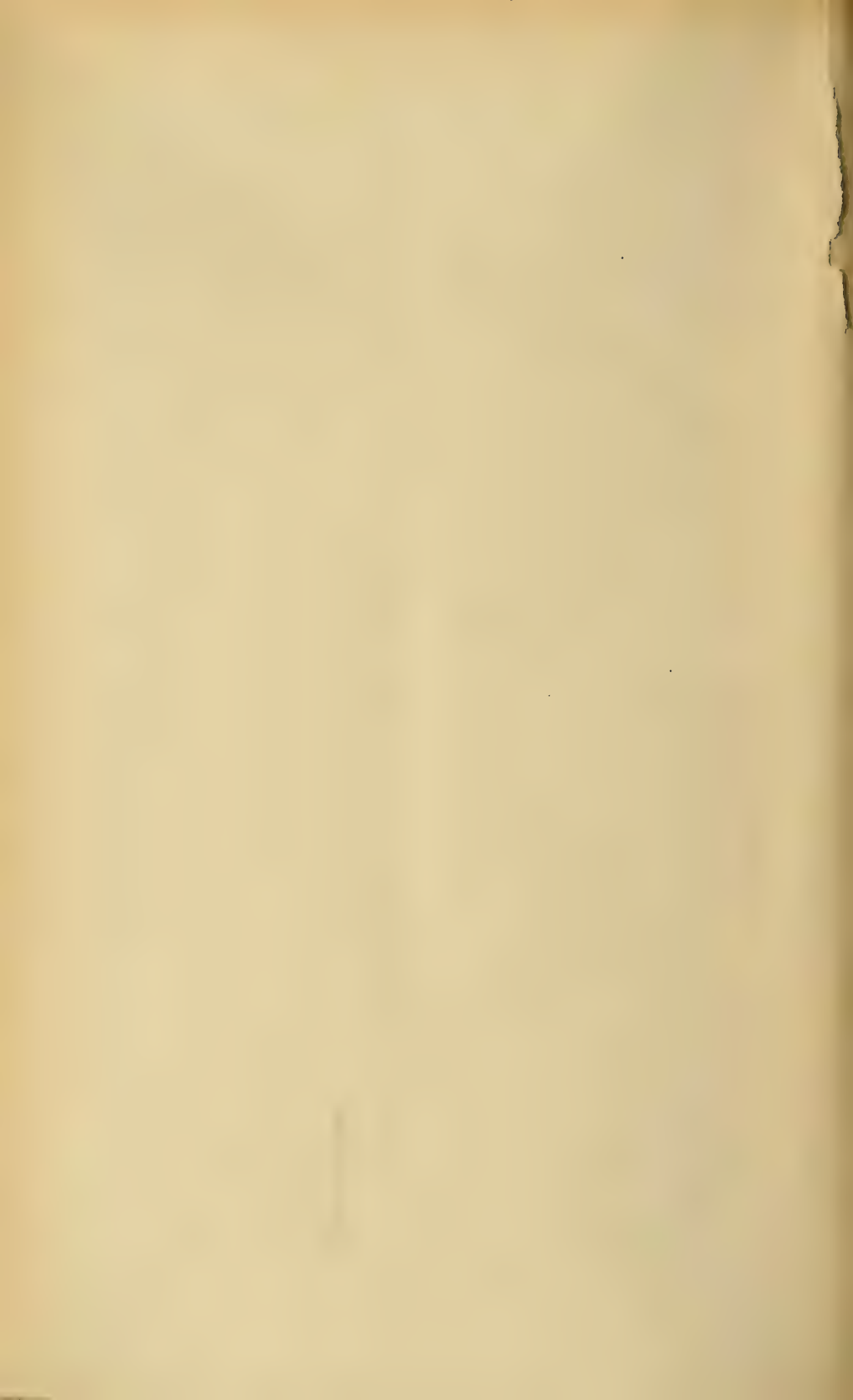
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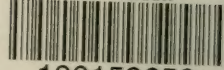
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